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AIRCRAFT OF TO-DAY

1. Aeronautics, [illegible]

2. European war, 1914 — Aerial operations.

I.

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PREFACE

SEVEN years ago I wrote my first book on aerial navigation, and although at that time few people believed that either aeroplanes or airships would ever be of much use, the subject was sufficiently "in the air" to justify the publication of the volume, which, indeed, proved a very gratifying success.

To-day the situation is very different. The Great War has proved the reality of the conquest of the air. Many authorities believe that the air will be the principal battlefield of the future, and that the aerial arm will be the first line of defence for Great Britain. This, however, is perhaps an exaggerated idea. Hitherto known as the "Fifth Arm," the time has come for this branch of the country's defences to take its place as one of the leading military services.

Whatever view is taken of these questions, there is no gainsaying the extraordinary interest now taken in aircraft, and the general public desire to be well informed on the subject.

My claim to be able to help in a small way to this end rests on the fact that for many years I have studied aeronautics in theory and practice, and have qualified as an aviator and a balloonist; and in each branch of aerial navigation I have had some experience. Twenty-five years ago I read Glaisher's "Travels in the Air," and I read it again and again, little thinking that I should one day be a humble disciple of the great aeronaut. Yet it was mainly due to such reading that my interest in the subject was awakened and my subsequent course of action guided, and I took part in aerial voyages in which British and World's records were created. From that time aeronautics has been to me both work and recreation. I have written much about this fascinating new science, and since 1909 have never ceased from urging its tremendous importance in national defence.

It is a bigger question now than ever it was, and it is only by the public taking an interest in it that this country will avert the disaster of being excelled by other Powers. It is my hope that the present book may stimulate both study and practice, and thus contribute, if it be only a little, towards this end.

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AIRCRAFT OF TO-DAY

CHAPTER I

FLYING IN ANCIENT LITERATURE

FROM the beginning the air has seemed unconquerable, yet intensely desirable. And now that it is at last navigated we feel that the human race has attained a greater glory: nothing so much as this has satisfied man's love of conquest and sense of power.

So impossible did it seem that few save poets and dreamers considered it. Strangely enough, with nothing scientific to justify their faith, they entertained visions that have now been realized. They saw as with the eye of faith. But the men who first ascended into the air used balloons, contrivances that had been only in the dimmest way foreshadowed in one or two idle speculations: where aviation has a place in mythology it appears always to have been inspired by the flight of birds, or by the poetic conception of angels and other superior winged beings.

To be able, like the birds, to roam at will in the air was in itself sufficiently desirable to account for the references in ancient literature, although their appearance in the mythology of nearly all races has suggested to many minds that in prehistoric times a civilization existed that possessed the art of flying. Certainly the idea is traceable in writings and in pictures of all the civilizations of which any record remains.

The Mahabharata of India, for example, contains, "Krishna's enemies sought aid of the demons, who built an aerial chariot with sides of iron and clad with wings. The chariot was driven through the sky till it stood over Dwaraka, in which Krishna's followers dwelt, and from there it hurled down upon the city missiles that destroyed everything on which they fell."

In Egypt were sculptures of winged men; and there were the winged bulls of Assyrian art.

Ovid tells the story of Phaeton, thus rendered in Addison's translation:

> "Meanwhile the restless horses neigh'd aloud,
> Breathing out fire, and pawing where they stood.
> Tethys, not knowing what had pass'd, gave way,
> And all the waste of heaven before them lay.
> They spring together out, and swiftly bear
> The flying youth through clouds and yielding air;
> With wingy speed outstrip the eastern wind,
> And leave the breezes of the Morn behind."

Phaeton was struck down by lightning, and tumbled to earth in a manner that many a daring aeronaut has only too closely followed.

When Icarus puts on his wings of quills joined by wax, and essays to fly, his father cries:

> "My boy, take care
> To wing your course along the middle air:
> If low, the surges wet your flagging plumes;
> If high, the sun the melting wax consumes.
> Steer between both: nor to the northern skies,
> Nor south Orion, turn your giddy eyes,
> But follow me: Let me before you lay
> Rules for the flight, and mark the pathless way.
> Thus teaching, with a fond concern, his son,
> He took the untried wings, and fix'd them on:
> But fix'd with trembling hands; and, as he speaks,
> The tears roll gently down his aged cheeks."

Then we are told, from the poet's imagination, of the beauties of the terrestrial scenes viewed from above, and, finally, how the heat of the sun dissolved the wax and Icarus came tumbling down.

Teutonic mythology contains the story of Wieland the Smith. This genius was deprived of the use of his feet by the King of Jutland. In order to travel about in spite of this difficulty, he made himself a flying cloak of feathers, and flew away with it to his own country.

Ariosto, in "Orlando Furioso," written in the fifteenth century, describes Astolpho, an English knight, flying to the source of the Nile, a suggestion for geographical exploration which has appealed strongly to aeronauts, and may some day be fulfilled:

> "'Twixt Atlas' shaggy ridges and the shore,
> He viewed each region in his spacious round;
> He turned his back upon Carena hoar,
> And skimmed above the Cyrenæan ground;
> Passing the sandy desert of the Moor,
> In Albajada, reached the Nubian's bound;
> Left Battus' tomb behind him on the plain
> And Ammon's now dilapidated fane."

In Hatton Turnor's "Astra Castra," mention is made of the Automaton Dove invented by Archytas of Tarentum:

"Many accounts of this sort appear to have been given in the name of Democritus by ignorant men, who sheltered themselves under the rank and authority of others. But that which Archytas the Pythagorean is related to have invented and perfected is not less marvellous, though it appears less absurd, for many men of eminence among the Greeks, and Favorinus the philosopher, a most vigilant searcher into antiquity, have, in a most positive manner, assured us that the model of a dove or pigeon formed in wood by Archytas was so contrived as by a certain mechanical art and power to fly: so nicely was it balanced by weights, and put in motion by hidden and enclosed air."

Roger Bacon, in the thirteenth century, described a plan of navigating the air. He assumed that the

atmosphere is a material of some consistency, capable
bearing upon its surface vessels, like ships are borne up
the surface of the water. He described the constructi
of an aerial machine, " which," he wrote, " must be a lar
hollow globe of copper, or other suitable metal, wroug
extremely thin, in order to have it as light as possib
It must then," he continued, " be filled with 'ethereal
or liquid fire,' and then launched from some elevat
point into the atmosphere, where it will float like a vess
on water." It cannot be ascertained from the writin
of Roger Bacon that he ever realized any of his projec
of flying by actual experiment; but, in concluding h
treatise upon this subject, he expressed himself thu
" There is certainly a flying instrument, not that I ev
knew a man that had it, but I am particularly acquaint
with the ingenious person who contrived it."

After expressing himself so confidently upon t
"hollow globe" method, he continued, " There may
made some flying instrument, so that a man sitting in t
middle of the instrument, and turning some mechanis
may put in motion some artificial wings which m
beat the air like a bird flying." Another instance, th
of the versatility of the great philosopher, who in so ma
matters saw far ahead of his time.

The author of " Astra Castra " quotes Kircher's " A
Magna Lucis et Umbrae " :

" I know that many of our fathers have been rescu
from the most imminent dangers among the barbaria
of India by such inventions. These were cast into priso
and whilst they continued ignorant of any means
effecting their liberation, some one, more cunning th
the rest, invented an extraordinary machine, and th
threatened the barbarians, unless they liberated his co
panions, that they would behold in a short time so
extraordinary portents, and experience the visible ang
of the Gods. The barbarians laughed at the threat.

ien had constructed a dragon of the most volatile paper, id in this he enclosed a mixture of sulphur, pitch, and ax, and so artistically prepared all his materials, that, hen ignited, it would illumine the machine, and exhibit ie following legend in their vernacular idiom, *The Anger* *God.* The body being formed and the ingredients pre- ared, he then affixed a long tail, and committed the achine to the heavens, and, favoured by the wind, it ared aloft towards the clouds. The spectacle of the ragon, so brilliantly lit, was terrific. The barbarians, eholding the unusual motion of the apparition, were nitten with the greatest astonishment."

For belief in the existence of a civilization, now sub- erged, on a continent familiar in literature as Atlantis iere is perhaps rather more than fable. Occultists aim by clairvoyance to have knowledge of such a civili- tion, and they declare that it possessed the secret of echanical flight. Francis Bacon in the New Atlantis akes one of their chief men say: "We imitate also the ghts of birds; we have some degrees of flying in the r; we have ships and boats for going under water . . . e have also means to convey sounds in trunks and pipes, strange lines and distances."

Bishop Wilkins, who died in 1672, wrote a work called Dædalus, or Mechanical Motions," in which he set forth ie several ways by which flying had been, or might be ttempted:

1. By spirits or angels.
2. By the help of fowls.
3. By wings fastened immediately to the body.
4. By flying chariots.

The second method refers to the fabulous throne of ai Kaoos of Persia.

The winged horse of Pegasus, and the legend of Hermes e winged messenger of the Gods, may also be remem- ered.

of rock-salt ground very fine in a marble mortar. Place, when you please, in a covering made of flying papyrus to produce thunder. The covering, in order to ascend and float away, should be long, graceful, well filled with this fine powder; but to produce thunder, the covering should be short, thick, and half-full."

What to the fanciful may seem almost like an anticipation of the electrolytic production of hydrogen comes from the "Dæmonolatria of Remigius": "There is no doubt the following will be considered incredible by all, and perhaps ridiculous by many, yet I can aver that two hundred persons testified to its truth, who, when I held the office of Duumvir, were condemned by me for arson, and thus atoned their crime of sorcery. On stated and regular days they assembled in a crowd on the banks of some lake or river, secluded from the observation of passers-by, and there they were in the habit of lashing the water with a wand received from a demon, till such time as vapours and mists were produced in large quantities, and with these they were wont to soar on high."

It is curious that Father Vassou, a missionary at Canton, in a letter dated September 5, 1694, mentions a balloon that ascended on the coronation of the Emperor Fo-kien in 1306.

Francesco Lana in the seventeenth century elaborated a theory that vessels entirely exhausted of air would ascend. He proposed using four hollow globes of copper, each twenty feet in diameter, and so thin that they would weigh less than an equal bulk of atmosphere. But the theory overlooked the fact that, in order to be light enough to ascend, the copper vessels would have to be so fragile that they would immediately collapse under atmospheric pressure.

In Dr. Johnson's "Rasselas" (published in 1759) in the "Dissertation on the Art of Flying," it is related that weary of the monotony of his existence in the Happy

Valley, the Prince of Abissinia sought to find some mea of escape from his confinement, but the precipitous cliff which encircled the valley, presented an insuperab obstacle to his desires. Finally, he conceived the ide of making his escape by flying, and with renewed ho he sought the aid of a machinist, also resident in th valley, and "eminent for his knowledge of the mechan powers, who had contrived many engines, both of u and recreation." He assented to give his assistance, b on condition that the prince would promise absolu secrecy respecting the invention. Then ensued th following dialogue :—

"Why," said Rasselas, "should you envy others s great an advantage? All skill ought to be exerted f universal good; every man has owed much to other and ought to repay the kindness that he has received."

"If men were all virtuous," returned the artist, " should with great alacrity teach them to fly. But wh would be the security of the good, if the bad could a pleasure invade them from the sky? Against an arm sailing through the clouds, neither walls, mountains, n seas could afford security. A flight of northern savag might hover in the wind, and light with irresistible vi lence upon the capital of a fruitful region. Even th valley, the retreat of princes, the abode of happines might be violated by the sudden descent of some of th naked nations that swarm on the coast of the souther seas!"

CHAPTER II

EARLY EXPERIMENTS AND PROJECTS

Y age has had its flying aspirants who, until the ht Brothers, Farman, Ader, and others succeeded, objects of ridicule and compassion. Of the earlier riments no reliable record remains, and doubtless in ewspaper times they were known only locally.

is said that a Saracen attempted to fly round the odrome at Constantinople in the presence of the eror Comnenus. This experimenter, it appears, had voluminous white robe stiffened with rods. He ed off a tower and for a moment hovered; then itation got the best of it, and he fell, sustaining grave ies from which he died.

the reign of the Emperor Nero, Simon the Magician red he would mount up into the air. And the story that he fulfilled his promise, with the aid of the rs of darkness, until, at the prayer of St. Paul, the ns released their hold and dropped Simon to earth.

is difficult to believe that an English monk in the of the Confessor flew, as is related, from the top tower for the distance of a furlong by the aid of s.

ny were the attempts to construct wings, until lli, in 1670, demonstrated that, for physiological ns, it was hopeless for man to attempt to fly, because cked the great muscular power in the breast allied wonderful lightness of bones which birds possess. a long time this declaration hindered further de-pment, scientists taking it for granted that the bird possessed great strength relatively to man, and that this was necessary to flight.

Besnier, a French locksmith, made a curious apparatus for flying about the year 1676–77, as is recorded in the *Journal des Savans*. Over each shoulder he laid a rod, each rod carrying two collapsing planes hinged, and each resembling an open book. The planes, which were of rectangular form, closed together with every upward stroke but formed a wide, flat surface with every downward movement. Two of these book-shaped wings were in front and two behind the aviator. The two front surfaces were moved by the arms, the two back ones were moved by the feet. Besnier did not imagine that he could soar aloft with this apparatus, but only that he could fly from an eminence in any desired direction. It is related that successful descents were made; but this is hardly likely.

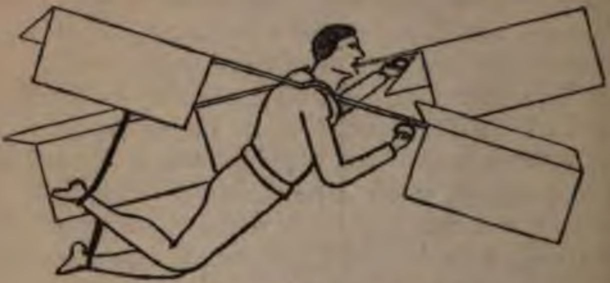


FIG. 1. BESNIER'S FLYING APPARATUS

The wings opened like a book on the downward stroke, and closed on being drawn upwards.

Hatton Turnor, in "Astra Castra," instances the experiment of the Marquis de Bacqueville, who in the year 1742, it is said, rose by means of imitation wings from his residence on the river-side, and directed his course across the Seine towards the gardens of the Tuileries, whither he had signified his intention of proceeding. At first he appeared to advance with tolerable eadiness and ease, but when about half-way over some- ing happened, which has never been thoroughly ex- ained, by which he seems to have been deprived of the

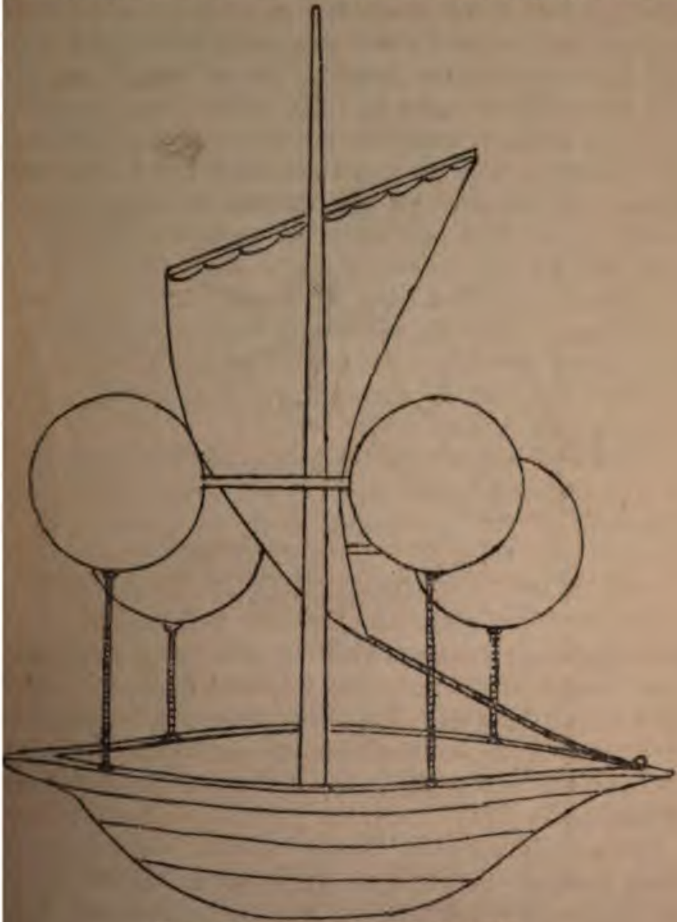


FIG. 2. FRANCESCO LANA'S AIRSHIP

wer of continuing his exertions. His wings ceasing to t, he sank to the ground, breaking one leg and suffering ther serious injuries.

Brescia, the Italian town where Francesco Lana lived, is in a district that enjoys long aeronautical traditions. It was here that one of the first aviation meetings was held; and at Mantua, which is not far away, Leonardo da Vinci, who wrote the first treatise on mechanical flight, and demonstrated the principle of the parachute, lived and worked from 1487 to 1499. This versatile genius, who was painter, sculptor, military and civil engineer, and architect, drew the first technical design for imitation wings. In his machine the aviator was to occupy a horizontal position and work the flying strokes with his arms and feet by means of ropes passing over pulleys. The wings resembled those of the bat, and consisted of several parts which flapped together in the upward stroke and spread out on the down stroke. A tail surface was provided between the parted legs. Here is a paragraph from Da Vinci's work:—

"The bird should with the help of the wind raise itself to a great height, and this will be its safety; because although all the revolutions mentioned may happen, there is time for it to recover its equilibrium, provided its various parts are capable of strong resistance so that they may safely withstand the fury and impetus of the descent, being provided with the safeguards mentioned, with their ligaments of strong, tanned leather and their tendons of very strong, raw silk; and no one need trouble to use iron joints, because they split under the strain of a twist, or wear out, so that there is no need to trouble about making them."

Leonardo da Vinci's manuscript on the "Flight of Birds" was written at Florence in 1505. It was among his papers at his death, and was left by his will to [illegible] companion Francesco Melzi. It accompanied many other Leonardo da Vinci manuscripts to Paris by the orde Napoleon in 1796. At the general restitution of only the Codex Atlanticus, as it is called, was sent to Milan. The treatise on flight remained at the Institut de France, was stolen, taken to Italy, bought by a Russian, and finally published in Paris in 1893.

Da Vinci's error was in the assumption that a man could manipulate wings quickly enough to raise his own body into the air. But this idea persisted for many centuries, and, indeed, has survived the criticism of Von Helmholtz, who, in 1872, demonstrated that man never could by his own muscular force, and aided by the most ingenious mechanism, raise his own weight into the air and sustain it there. To the possibility of a more extended use of the motorless glider that may conceivably come with a more complete knowledge of the atmosphere than we now possess reference will be made in another place.

The idea of a parachute also came from Leonardo da Vinci. "If a man," he wrote, "carry a domed roof of starched linen 18 feet wide and 18 feet long, he will be able to throw himself from any great height without fear of danger." This idea was taken up again by the Venetian Faust Veranzio in 1617. "With a square cloth stretched on four poles of equal length," said he, "and having a cord attached to each corner, a man can throw himself from the top of a tower or from some other lofty place without danger. For although at the time there might not be any wind, the force of that which falls causes a wind, which sustains the cloth, so that it does not fall violently, but little by little. Man, then, must compare himself with the size of the cloth."

The first to experiment with regard to the extent of wing-surface necessary to sustain a man in the air, calculated from the proportions of weight and wing-surface in birds, was Karl Meerwein, Inspector of Public Buildings for Baden. According to this authority, a man weighing fourteen stone would require a surface of 126 square feet. Lilienthal's calculations led to the same result. Meerwein's apparatus, made in 1781, was a spindle-shaped surface, curved as in the accompanying diagram. The aviator was to be fastened in the middle, holding a rod which worked the wings. Meerwein made one attempt to fly, but was unsuccessful.

One of the earliest attempts to fly was made in Scotland by an Italian, in the seventeenth century, who undertook to fly from the battlements of Stirling Castle to the shores of France. He made a glider composed of feathers. A broken thigh was the reward of his daring, and he attributed this accident to the employment of fowls' feathers, which had an affinity for the earth, and thought that he ought to have used eagles' feathers solely, for they would have kept him aloft!

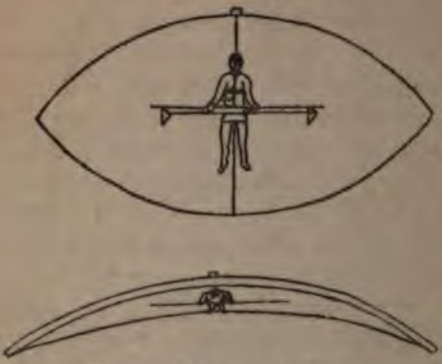


FIG. 3. MEERWEIN'S WINGS

Flight was to be obtained with the aviator in a horizontal position. The two sides of the apparatus were to be alternately opened and closed.

It is not commonly known that Emanuel Swedenborg, the great Swedish theologian, designed a flying machine. Particulars were published in the Journal of the Aeronautical Society of July, 1910, and from the introduction the following is quoted :—

" Writing from Rostock to his brother-in-law Benzelius, on September 8, 1714, Swedenborg—then a young man of twenty-six years—mentioned fourteen mechanical inventions which he had then recently completed; among these is cited 'a Flying Vehicle, or the possibility of

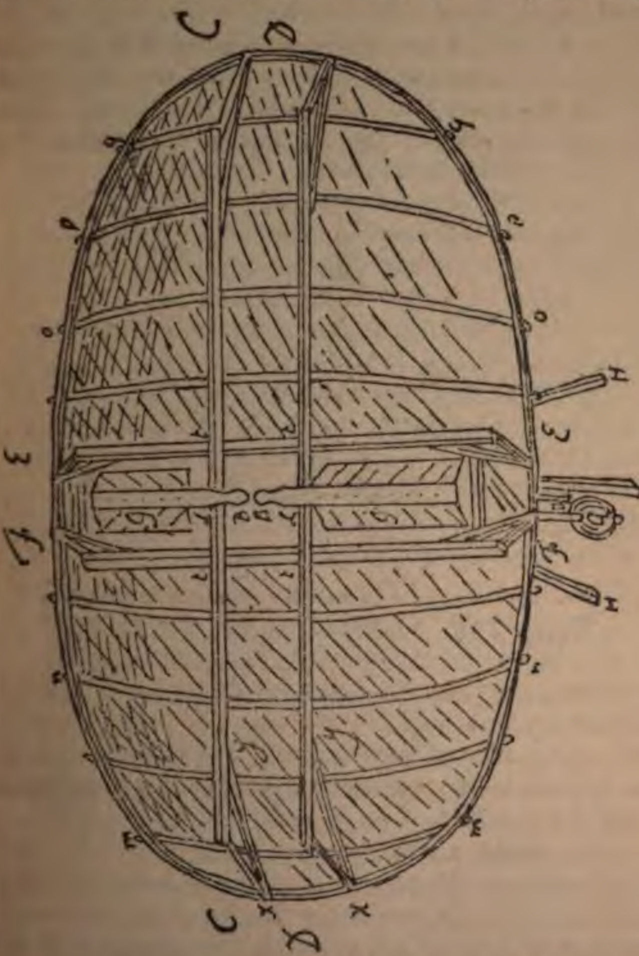


FIG. 4. SWEDENBORG'S "FLYING VEHICLE" ("Aeronautical Journal")

being sustained in the air, and being conveyed through it.' The manuscript embodying this invention, together with the drawing here reproduced, was sent to Benzelius a few months later and is preserved in the cathedral library at Linkoping in Sweden. Soon after his return to Sweden in 1715, Swedenborg undertook the publication of a journal devoted to physics and mechanics, entitled Dædalus Hyperboreus, in the fourth number of which, published in 1717, appeared the account reprinted below under the designation of 'The published account.' There is no need to enlarge on the merits of Swedenborg's invention, which, incidentally, it should be noted is described merely as 'a suggestion'; it will be obvious, at any rate, that it is the first rational proposal for a flying machine of the aeroplane type, as opposed to the lighter-than-air vessel invented by Francesco Lana some fifty years earlier and somewhat scornfully rejected by Swedenborg. We are indebted for the following translation—by Hugo Lj. Odhner and Carl Th. Odhner—to the pamphlet published by the Swedenborg Scientific Association of Philadelphia, a copy of which was kindly lent by the Reverend James R. Rendell, of Accrington."

After a full specification of the proposed machine follow the proofs and notes.

"PROOFS

"(1) From eagles or gleads, which are able to lie still on their wings or on their expanse, or sway in the air.

"(2) From paper-kites, which often in calm weather are able to keep themselves in the air, and rise higher and higher up by only a slight motion, and yet not tip over, although surrounded by wood and other heavy materials.

"(3) That Kirchberg and others tell about such things, although nothing (—) is seen expanded.

"(4) That the wind can lift up very heavy materials, so that when it blows against a gate with force it can blow it open even though two men be pushing against it when yet it is often 16 square ells in extent. How, then, would it act on a surface of 150 square ells, with the wings helping along?

"(5) A student with a side-cape fell unharmed down from Skara church tower in a strong wind.

"(6) A kite, the higher it reaches, the less motion is needed to keep it in the air, as is apparent; while down by the ground it has to be lifted up by motion.

"OBSERVATA

"A machine such as this can be made to go when there is a strong wind; otherwise it will remain still.

"It may be drawn forward on the rollers, where the ground is even. Or it may be pushed down from a roof, after it has been weighted with ballast, to the weight of a man."

A writer in the *Westminster Gazette* quotes from an Italian newspaper an article by Dr. Locatelli, who relates the discovery in the Municipal Archives of Bergamo of a manuscript written "by a gentleman in London to his friend in Venice in reference to the flying machine which amid universal applause was there seen guided in the air." Dr. Locatelli cites a number of contemporary writings referring to the machine, the invention of Father Andrea Grimaldi, of Civita Vecchia, who produced it on his return from the East Indies. The letter is given here in full for the sake of the wonderful imagination of its minute details.

"LONDON, *October* 18, 1751.

"DEAREST FRIEND,

"A few days ago there arrived here, from the East Indies by way of Lisbon, a man of the most astonishing talent ever seen in this world. They say he is an Italian monk, a native of Civita Vecchia, by name Andrew Grimaldi, about fifty years of age, and of medium height. Under the orders of the Provincial Father and of the Propaganda he spent about twenty years in travelling in the furthest East, where in the intervals of his religious duties he devoted himself for the space of fourteen years, with much labour and expense, to perfecting the construction of the most marvellous and wonderful machine which mechanical and mathematical art could produce.

"The machine is a box or trunk of the most curious workmanship and texture, which by means of clockwork rises into the air and flies with such lightness and speed that it can travel at the rate of seven leagues an hour. It is made in the shape of a bird. The wings measure 22 feet from tip to tip, the body is composed of pieces of cork skilfully put together, firmly joined by wire, and covered with vellum and feathers. The wings are made of catgut and whalebone, and are also covered with vellum and feathers, and each wing folds in three joints. In the body of the machine there are contained thirty wheels of singular workmanship, two brass globes, and some small chains which alternately expand and contract; and, with the help of six brass vessels, each containing a certain quantity of quicksilver, which run into various channels with internal divisions, the artist is able to keep the machine in equilibrium and properly balanced. Then, by means of the friction between a properly tempered steel wheel and a large and powerful magnet, the whole machine moves forward with a regular motion; for it cannot fly either in a gale or in a dead calm.

"This wonderful machine is directed and guided by a long tail seven spans long, which is attached to the knees and to the ankles of the driver by narrow leather straps; and so by stretching his legs to the right or the left he can move the machine to whichever side he likes. The head also is of most beautiful shape, and represents that of an eagle. The entire beak is made of Arabian buckhorn of a peculiarly transparent kind. The eyes are of glass, and so natural that they appear to be alive as they move on their axis by means of two wires attached to the inside of the beak. Eyes and beak are in continuous motion during the flight of the machine. This lasts only three hours, and then the wings gradually close. When the driver perceives this he lets himself fall gently to earth upon his own feet, in order to rewind the wheels of the clockwork, and then resumes his seat above the wings to continue his flight.

" He himself says that, if by some ill-luck one of the wheels jammed, or the framework were to break, he would inevitably fall headlong to the ground. For this reason he does not rise much beyond the height of the trees, and he has not run the risk more than once of passing over the sea, which he did from Calais to Dover, arriving the same morning in London, whither he said he was drawn, partly by curiosity, partly by the fame of our learned men and professors of mechanical science, who seem in the present day to surpass all others in the known world both in the design of their works and in the technical skill with which they construct them.

" He has already had an interview with two of the leading men in that branch of science, who have seen his machine at work, and he has promised to send them by next Christmas an entire and complete set of wheels, more accurately finished, and not so liable to accidents, which will only occupy half the space of the old ones, with this difference into the bargain, that they will work more quietly, and will continue revolving on the average for six hours, so that the machine will fly at the rate of thirty miles an hour without rewinding the clockwork.

" The exquisite choice of the feathers which adorn this bird surpasses the imagination and skill of the ablest painters. The most beautiful variety of colour and shade is there represented: brilliant sky-blue, gold, ruby, green, brown, and white, and these colours all blended in such delightful fashion that the like has never been seen before.

" The inventor recently made a flight from the Park of London to Windsor Terrace, and returned thence, the whole expedition taking less than two hours. On His

Majesty the King's birthday he proposes to fly from the top of the monument at the sixteenth hour (Italian time), circle round the entire city of London and its suburbs, and land in the Park about the eighteenth hour. What I have told you is true, though it is not all, because time fails me. Farewell."

The "Observer" of June 30, 1811, contains the following item of news:

"The taylor, Büblinger, has been unsuccessful in his promised attempt at flying with the wings he has made. On the 1st inst. he placed himself on the walls of Ulm, at the edge of the Danube, for the purpose of flying over that river; but no sooner had he leaped from the wall, than one of his wings broke and he fell into the water, and must have been drowned had not some boats gone to his assistance."

A Viennese watchmaker named Degen, in 1808 and in 1812, attached a flying machine to a balloon, but soon abandoned the flying for simple ballooning.

Sir George Cayley, Bart., a famous Yorkshire savant in 1809–10 published in "Nicholson's Journal" a treatise on aerial navigation which entitles him to be called the "father of aviation." In it he anticipated the main lines upon which success was achieved a century later. From the introduction to a reprint published by the Aeronautical Society in 1910 the following is quoted:—

"After analysing the mechanical properties of air under chemical and physical action, he proceeded to investigate the power necessary for aerial locomotion, and his knowledge of steam-engines led him to point out the fallacy of hopes of any success in this direction in the absence of a given power within a given weight. This led to his invention of the air-engine; while he also seems to have clearly foreseen the gas-engine, and to have had some idea of electricity as the necessary motor. Indeed he invented an arrangement for applying electric power to machinery, though it does not seem to have been put to any important use. His optical invention may also be mentioned here, being an instrument for testing the purity of water by the abstraction of light, which was used very successfully in investigating the Thames waters.

" In aeronautical science he was far ahead of his contemporaries. Had his suggestions been adopted and money been forthcoming for the purpose, a dirigible balloon might have hovered over the field of Waterloo and brought news of Blücher's progress to the anxious Duke. In 1810 he had publicly stated that he could at once construct a balloon 'that should carry its passengers at twenty miles an hour'; and judging from the knowledge displayed in his writings it is quite possible to believe it.

" In the year of Queen Victoria's coronation he endeavoured to establish an aeronautical society, but without success, for ballooning was in bad odour in those days, and generally regarded as the exclusive property of mountebanks and showmen at country fairs."

A few experiments with wing-surfaces in the first half of the nineteenth century scarcely need be mentioned.

There was living at Llandudno in 1910 a widow, Mrs. Miriam Jones, who on July 14 of that year celebrated her ninety-first birthday, and she recalled the fact that her husband made a glider with the wings of birds, and experimented in short planing excursions from the rocks until a fall disabled him.

Little further light was shed on the subject until Francis Wenham, in 1865 and 1867, showed that the lifting power of a plane of great superficial area could be obtained also by dividing the large plane into several parts superimposed, or superposed—i.e. arranged in tiers. m's machine had six planes. When he placed in a strong wind with this apparatus, he was lifted rown backwards. He made further experiments, but never achieved anything approaching flight. His work is fully described in the "Transactions of the Aeronautical Society," 1867.

John Stringfellow began his famous experiments in 1868.

In 1872 H. von Helmholtz proved to the satisfaction of his contemporaries and of many that lived afterwards that man would never by his own muscular force, and aided by the most ingenious mechanisms, be able to raise his own weight in the air and sustain it there. He also riddled with shrewd criticism the attempts to make balloons dirigible. It was not until the two Lilienthals, in Germany, about the years 1885–1889, discovered the great lifting power obtained by driving curved aeroplanes against the wind that practical aviation again revived. Horatio Phillips began important investigations as to curved surfaces in 1884, and in that year Hargrave, of box-kite fame, commenced work.

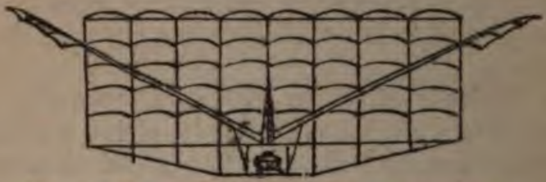
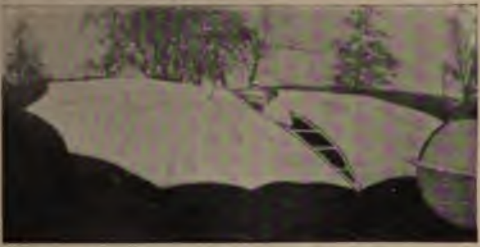


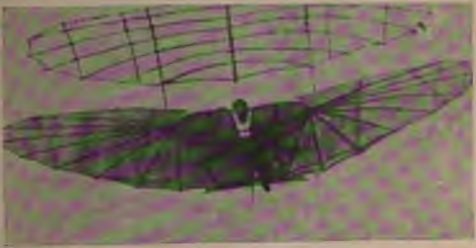
FIG. 5. WENHAM'S GLIDER. VIEW FROM REAR

Wenham discovered the use of superposed planes. The winged rudder propellers were worked by the legs of the aviator. No actual flight was achieved.

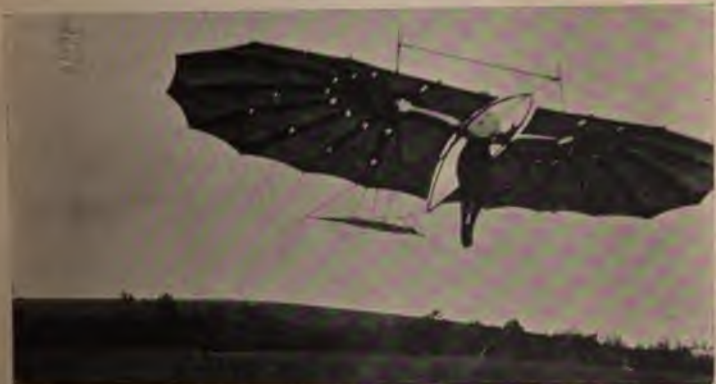
Otto Lilienthal held that it was necessary to begin with "sailing" flight, and that first of all the art of balancing in the air must be learned by practical experiments. He made many flights himself of a kind we now call "gliding." From a height of 100 feet he glided a distance of 700 feet without exertion, and, moreover, he found that he could deflect his flight to the left or right by moving his legs, which were hanging freely from the seat. Lilienthal



Pilcher's Glider, "The Gull"



Lilienthal's Biplane Glider Soaring



Pilcher's Glider, "The Hawk"

On this machine the Great Pioneer was killed on October 2nd, 1899.
(Photos lent by the Aeronautical Society.)

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attached a light motor to his machine, developing 2½ horse-power and weighing nearly ninety pounds, and he had to increase the size of his planes to sustain this weight. Unfortunately, in testing a horizontal steering arrangement he fell from a height of 50 feet and broke his spine. He left a mass of valuable data for the use of other experimenters.

Percy S. Pilcher, a young English marine engineer, succeeded in 1896, with a glider of 560 square feet, weighing nearly fifty pounds, in making several good flights, attaining a speed of thirty miles per hour—enough for horizontal support. He patented his design. He also built an oil-engine of 4 horse-power; but while in flight near Rugby a weak part of the machine broke, and Pilcher fell 30 feet, and died thirty-four hours later.

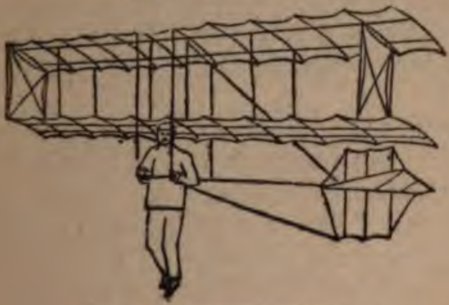


FIG. 6. CHANUTE GLIDING

Chanute sought to make equilibrium automatic by having the surfaces movable. He made over 700 glides with this apparatus.

Chanute forged the next link in the chain. This famous American experimenter directed his attention to obtaining automatic equilibrium. He departed from former practice by making the surfaces movable. In 1896 he built five large machines of four different types. The first was a Lilienthal glider, built by Chanute's assistant, A. M. Herring. But after he had made a great number of successful glides with this machine the principle of its design was decided to be unsound. Then Chanute tried a "multiple-winged" machine, consisting of four pairs of superimposed curved planes, with a single plane above all, and two wings at the rear. Three hundred flights were made with this machine, and then the "double-deck" type of rectangular planes—a distinct prototype of the Wright machine—was produced.

The machine weighed only thirty pounds. The speed was about twenty-four miles per hour, and the angle of descent from 7½ to 11 degrees. Some 700 glides were made with the apparatus without an accident.

Herring attempted to apply a motor to the "double-deck" machine, experimenting with various types of engine.

But before this period notable successes had been achieved in France and England, and in each case, curious to relate, the pioneer was regarded by his countrymen with indifference. Maxim in 1894 made a flying machine. He demonstrated the efficiency of this aeroplane as a lifting apparatus, and that it did not fly was due chiefly to the fact that in those days the light petrol motor did not exist, and that the inventor had to use a steam-engine.

CHAPTER III

THE PRACTICAL BALLOON

a. Historical

As long ago as 1767 Dr. Black, of Edinburgh, suggested that a thin bladder could be made to ascend in the air if filled with "inflammable air," as hydrogen gas was called in those days; and Cavallo, in 1782, actually succeeded in sending up a soap-bubble filled with hydrogen gas. It was in November of that year that the brothers Stephen and Joseph Montgolfier conceived the idea of using hot air for lifting loads into the air. That idea is said to have occurred to them while they were watching smoke curling up the chimney. Hot-air balloons are now called "Montgolfières."

In the following year, Euler, in Russia, was working at the problem, and the Montgolfiers gave their first public exhibition. According to the chronicles of the event:

"On Thursday, June 5, 1783, the States of Vivarais being assembled at Annonay (thirty-six miles from Lyons), Messrs. Montgolfier invited them to see their new aerostatic experiment. Imagine the surprise of the deputies and spectators on seeing in the public square a ball, 110 feet in circumference, attached at its base to a wooden frame of 16 feet surface. This enormous bag, with frame, weighed 300 pounds, and could contain 22,000 feet of vapour.

"Imagine the general astonishment when the inventors announced that, as soon as it should be filled with gas (which they had a simple means of making), it would rise of itself to the clouds. One must here remark that, notwithstanding the general confidence in the knowledge and wisdom of Messrs. Montgolfier, such an experiment appeared so incredible to those who were present that all doubted of its success.

"But Messrs. Montgolfier, taking it in hand, proceed to make the vapours, which gradually swell it out till it assumes a beautiful form. Strong arms are now required to retain it; at a given signal it is loosed, rises with rapidity, and in ten minutes attains a height of 6,000 feet; it proceeds 7,668 feet in a horizontal direction, and gently falls to the ground."

In August of the same year occurred the famous flight from the Champ de Mars, when for the first time the name "ballon" was given to an aerostat. The filling commenced on August 23, in the Place des Victoires, but, as the crowd was immense, the balloon was moved on the night of the 26th to the Champ de Mars, a distance of two miles. This was done secretly, and in the dark, to avoid the mob. A description by an eye-witness runs as follows:—

"No more wonderful scene could be imagined than the balloon being thus conveyed, preceded by lighted torches, surrounded by a 'cortège,' and escorted by a detachment of foot and horse guards. The nocturnal march, the form and capacity of the body, carried with so much precaution; the silence that reigned, the unseasonable hour, all tended to give a singularity and mystery truly imposing to all those who were unacquainted with the cause. The cab-drivers on the road were so astonished that they were impelled to stop their carriages and to kneel humbly, hat in hand, whilst the procession was passing.

"In the morning the Champ de Mars was lined with troops, every house to its very top, and every avenue was crowded with anxious spectators. The discharge of a cannon at 5 p.m. was the signal for ascent, and the globe rose, to the great surprise of the spectators, to a height of 3,123 feet in two minutes, where it entered the clouds. The heavy rain which descended did not impede it, which tended to increase the surprise. The idea that a body leaving the earth was travelling in space was so sublime, and appeared to differ so greatly from ordinary laws, that all the spectators were overwhelmed with enthusiasm. The satisfaction was so great that ladies in the latest fashions allowed themselves to be drenched with rain to avoid losing sight of the globe for an instant. The balloon, after remaining in the atmosphere three-quarters of an hour, fell in a field near Gonesse, a village fifteen miles from the Champ de Mars. The descent was imputed to a tear in the silk."

There was great stir in all countries in acknowledgment of the achievements of the Montgolfiers; but nobody risked a voyage in the air until Pilâtre de Rozier and the Marquis d'Arlandes ascended in a hot-air balloon in 1784, and passed over Paris in it. In the same year a huge balloon, 130 feet in height, ascended from Lyons with seven passengers, burst when at a height of 3,000 feet, but descended without injury to the passengers. A balloon, of course, does not "burst" like a child's air-ball: it is not an elastic envelope very highly inflated, but merely a bag filled with gas.

On December 17, 1784, a hydrogen balloon took up Messrs. Robert and Charles to a height of 10,000 feet.

The first ascent in Great Britain was also in that year. In the *London Chronicle* of August 27 appeared the following letter from a correspondent:—

"EDINBURGH.
"*August* 27, 1784.

"Mr. Tytler has made several improvements upon his fire balloon. The reason of its failure formerly was its being made of porous linen, through which the air made its escape. To remedy this defect, Mr. Tytler has got it covered with a varnish to retain the inflammable air after the balloon is filled.

" Early this morning this bold adventurer took his first aerial flight. The balloon being filled at Comely Garden, he seated himself in the basket, and the ropes being cut he ascended very high, and descended quite gradually on the road to Restalrig, about half a mile from the place where he rose, to the great satisfaction of those spectators who were present.

" Mr. Tytler is now in high spirits, and in his turn laughs at those infidels who ridiculed his scheme as visionary and impracticable. Mr. Tytler is the first person in Great Britain who has navigated the air. "

Lunardi's famous ascent from London took place a few weeks later. While the aeronaut hovered over London the King was in conference with some of his ministers, and His Majesty, learning that Lunardi was in the sky, is reported to have said: " We may resume our own deliberations at pleasure, but we may never see poor Lunardi again ! " On this, it is further stated, the conference broke up, and the King, attended by Pitt and other chief officers of State, continued to view Lunardi through telescopes.

The public press paid a worthy tribute to the hero of the hour, and one last act of an exceptional character was carried out in his honour, and remains in evidence to this hour. In a meadow in the parish of Standon, near Ware, there stands a stone protected by an iron rail marking the spot where Lunardi landed.

For a century the balloon scarcely altered in design, although improvements were effected in the method of inflation, the construction of the valve, the introduction of the ripping panel, and in the quality of the scientific instruments employed.

In most cases, in order to defray the expenses of ascents, balloonists conducted their operations before the public, who paid to see the novelty, so that, with the exception of occasional ascents, chiefly on the Continent, by savants, ballooning became associated with the world of amusement. It was not until Creswick and James Glaisher obtained grants from the British Association, in 1862, to enable them to make various scientific observations in the air that ballooning in England was lifted out of the showman's province.

Glaisher's systematic observations, although they have since been corrected in many important respects, were of great value. The story of his adventures, and the results of his observations, are given fully in that delightful aeronautical classic, "Travels in the Air," from which one remarkable incident is here quoted. This memorable ascent was made on September 5, 1862, from Wolverhampton, by Glaisher and Coxwell. After describing a steady climb upwards to 29,000 feet, Glaisher continues :—

"Shortly afterwards I laid my arm upon the table, possessed of its full vigour, and, on being desirous of using it, I found it powerless ; it must have lost its power momentarily. I tried to move the other arm, and found it powerless also. I then tried to shake myself, and succeeded in shaking my body. I seemed to have no limbs. I then looked at the barometer ; and whilst doing so my head fell on my left shoulder. I struggled and shook my body again, but could not move my arms. I got my head upright, but for an instant only, when it fell on my right shoulder, and then I fell backwards, my back resting against the side of the car, and my head on its edge ; in this position my eyes were directed towards Mr. Coxwell in the ring. When I shook my body I seemed to have full power over the muscles of the back, and considerable power over those of the neck, but none over either my arms or my legs ; in fact, I seemed to [illegible] none. As in the case of the arms, all muscular power was lost in an instant from my back and neck. I dimly saw Mr. Coxwell in the ring, and endeavoured to speak, but could not; when in an instant intense black darkness came, the optic nerve finally lost power suddenly. I was still conscious, with as active a brain as at the present moment while writing this. I thought I had been seized with asphyxia, and that I should experience no more, as death would come unless we speedily descended. Other thoughts were actively entering my mind, when I suddenly became unconscious as in going to sleep. I cannot tell anything of the sense of hearing; the perfect stillness and silence of the regions six miles from the earth (and at this time we were between six and seven miles high) is such that no sound reaches the ear."

While Glaisher was unconscious Coxwell's hands were powerless. The latter, in order to prevent ascending to still higher regions, opened the valve-cord with his teeth. Glaisher continues:

"My last observation was made at a height of 29,000 feet; at this time (one hour, fifty-four minutes) we were ascending at the rate of 1,000 feet per minute; and when I resumed observations we were descending at the rate of 2,000 feet per minute. These two positions must be connected, taking into account the interval of time between, viz. thirteen minutes, and on those considerations the balloon must have attained the altitude of 36,000 or 37,000 feet. Again, a very delicate minimum thermometer read—12 degrees, and this would give a height of 37,000 feet. Mr. Coxwell, on coming from the ring, noticed that the centre of the aneroid barometer, its blue hand, and a rope attached to the car, were all in the same straight line, and this gave a reading of 7 inches, and leads to the same result. Therefore these independent means all lead to about the same elevation, viz. fully *seven miles*."

Probably Glaisher was in error in assuming that the balloon continued to ascend at the same rate after he lost consciousness. It should be remembered, also, that his instruments were not of a high order, according to modern standards.

At Berlin on July 31, 1901, Süring and Berson attained an altitude of 35,433 feet in the "Preussen" balloon. The temperature at that great altitude was 38 degrees below zero (Fahrenheit).

One of the landmarks in aerostatic literature is the account given by Mason of the famous voyage of the "Great Nassau Balloon." The voyage made by Mason was under the guidance of the celebrated aeronaut Green, and was organized by Robert Hollond. The proprietors of Vauxhall Gardens had a large balloon in constant use in the gardens, which had been constructed for them by Green. It was the "last word" in ballooning up to that time. It was shaped like a pear, 60 feet high, 50 feet across; "a form and proportion," says Mason, "admitted to be most consistent with elegance of appearance, and most adapted to the wants and circumstances of aerostation." Modern ordinary balloons, it should be stated, are, almost without exception, spherical. The Nassau balloon held 85,000 cubic feet of gas, and was able to raise nearly 4,000 pounds, including its own weight, and accessories.

At half-past one o'clock on November 7, 1836, the great balloon rose, and drifted on a north-westerly wind over Kent. When over Canterbury, the aeronauts sent down a letter in a parachute for the mayor. The same thing was done at Dover, and both letters reached their destination.

Over the Channel the travellers attempted to test the new invention of the guide-rope. To provide against the increase of weight due to the humidity of the night atmosphere, they began lowering this rope, with floating ballast attached. But they were then already across the Channel.

During the night they found themselves in the centre of a district which blazed with innumerable fires studded in every direction to the full extent of their visible horizon. This was the district of Liége. To its brilliant lights the blackness of night succeeded. "Nothing could exceed its density," says Mason—"not a single object of terrestrial nature could anywhere be distinguished; an unfathomable abyss of darkness visible seemed to encompass us on every side." It was then that the advantage of the guide-rope began to be felt in indicating the changes of level in the ground. The cold during the night was intense—water and oil were completely frozen—but, owing to the absence of all currents of air, the natural result of their situation, and one of the peculiar characteristics of balloon voyaging, the travellers suffered little from this cause.

In the morning they prepared to come down. They saw a grassy valley, and after missing it owing to a current of air near the ground, which threatened to dash them into a wood, they rose, floated over a hill, and, after another attempt, descended in safety. "Where are we?" they said to the country folk, who stood about amazed. "In the Duchy of Nassau, two leagues from Weilburg. And where do you come from?" "From London, which we left yesterday." Amazement and incredulity. Finally, the balloon was packed and carted to Weilburg, where the travellers were fêted and lionized, and the balloon was there and then "christened." It was named the "Great Balloon of Nassau," by Mdlle. Theresa, the daughter of the Baron de Bibra, Grand Maître des Eaux et Forêts.

The largest balloon ever made for free ascents (i.e. as distinct from captive ascents) was the "Géant" of "Nadar" (Felix Tournachan). This monster was of 215,000 cubic feet capacity. But the huge craft possessed another novelty besides that of exceptional size. It was provided with a subsidiary balloon, called the "compensator," the idea of M. L. Godard, the function of which was to receive any gas expelled in ascending, and thus prevent loss during the voyage. The gas envelope was, for greater strength, virtually double, consisting of two identical balloons, one within the other, each made of white silk of the finest quality, and costing about 5s. 4d. per yard. No less than 22,000 yards of this silk were required, and the sewing up of the gores was done entirely by hand. The small compensating balloon had a capacity of about 3,500 cubic feet, and the complete aerostat, when fully inflated, was calculated to lift 4½ tons. The car was of proportionate and unparalleled dimensions, and of most elaborate design. It contained two floors, of which the upper one was open, the height of all being nearly 7 feet, with a width of about 13 feet.

The first ascent was made on October 4, 1853, from the Champ de Mars, and no fewer than fifteen people were launched together into the sky. Of these "Nadar" was captain, with the brothers Godard as lieutenants. There was the Prince de Sayn-Wittgenstein; there was the Count de St. Martin; and there was a lady, the Princesse de la Tour d'Auvergne. The balloon came to earth at nine o'clock at night near Meaux, and, considering all the provision which had been made to guard against rough landing, it can hardly be said that the descent was a happy one. It appears that the car dragged on its side for nearly a mile, and the passengers, far from finding security in the seclusion of the inner chambers, were glad to clamber out above, and cling as best they might to the ropes.

Many of the party were bruised more or less severely, though no one was seriously injured, and it was reported that such fragile articles as crockery, cakes, confectionery, and wine bottles, to the number of no less than thirty-seven, were afterwards discovered to be intact, and received due attention. It is further stated that the descent was decided on contrary to the wishes of the captain, but in deference to the judgment of the experienced Godards, it being, apparently, their conviction that the balloon was heading out to sea, whereas, in reality, they were going due east, "with no sea at all before them nearer than the Caspian."

This huge balloon's next ascent was even more unfortunate. Ascending from the Champ de Mars, it travelled to Hanover. The descent was very rough, one of the passengers sustaining a broken arm and others being cut and bruised.

"Nadar," who died within a fortnight of his ninetieth birthday in March, 1910, was a journalist, caricaturist, and photographer, as well as a balloonist, who believed in the coming day of mechanical flight. He was the organizer of the balloon service from Paris at the time of the siege.

There have been many large balloons in France, notably the "Aigle," 146,000 cubic feet, of Jacques Balsan, but the largest on record was the captive balloon of Henry Giffard; this had a capacity of 450,000 cubic feet. It made two ascents from Ashburnham Park in 1869.

Most modern balloons are from 20,000 to 80,000 feet capacity, but a notable exception was the "Mammoth" of 108,000 cubic feet capacity, built in London by A. E. Gaudron, in 1907, for long-distance voyages. A trial ascent with fifteen passengers, among whom were Bennett Burleigh, the famous war correspondent, and the present writer, was made in May, 1907, the balloon descending near Basingstoke in a thunderstorm.

On October 12, 1907, an attempt was made to break the world's distance record of 1,193, miles, held by the Count de La Vaulx. The balloon ascended from the Crystal Palace and crossed the North Sea from Yarmouth to the north coast of Denmark, a sea-distance of 360 miles, the greatest oversea balloon voyage ever made.

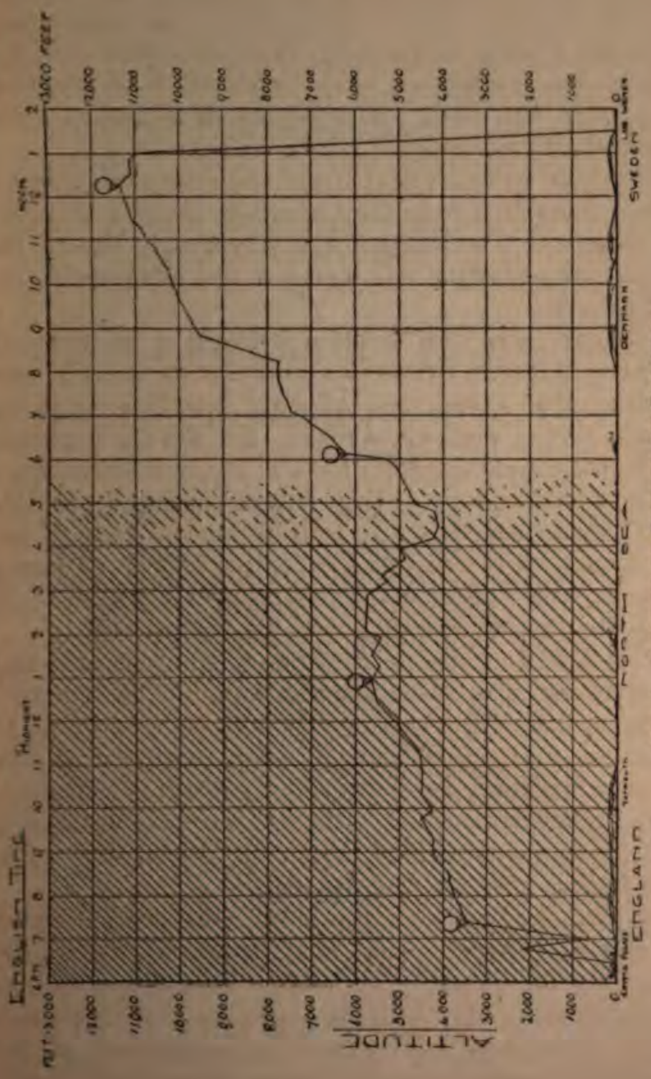


FIG. 7. LONDON TO SWEDEN BY BALLOON

The journey terminated at the shore of Lake Wener in Sweden, the total distance being 702 miles, the longest voyage up till that time ever made from England. The aeronauts were A. E. Gaudron (the pilot), J. L. Tannar, and the author of this book.

The same balloon ascended from the Crystal Palace on November 18, 1908, and, crossing the sea to the Belgian coast at Ostend, went across the north of Germany, and was driven down by snow after a flight of thirty-one and a half hours, at Mateki Derevni, in Novo Alexandrovsk, Russia, a distance, as the crow flies, of 1,117 miles. The aeronauts on that occasion were as before, with the difference that Captain E. M. Maitland took the place of J. L. Tannar.

Major B. Baden-Powell long since suggested a balloon voyage up the Nile, taking advantage of the constant northerly wind that blows in that region. In a paper before the British Association, Major Baden-Powell said:

"I should suggest several balloons, one of about 60,000 cubic feet, and, say, six smaller ones of about 7,000 cubic feet; then, if one gets torn or damaged, the others might remain intact. After a time, when gas is lost, one of the smaller ones could be emptied into the others, and the exhausted envelope discharged as ballast; the smaller ones would be easier to transport by porters than a big one, and they could be more easily secured on the earth during contrary winds. Over the main balloon a light awning might be rigged, to neutralize, as far as possible, the changes of temperature. A lightning-conductor to the top of the balloon might be desirable. A large sail would be arranged, and a bifurcated guide-rope attached to the end of a horizontal pole would form an efficient means of steering. The car would be boat-shaped and water-proof, so that it could be used for a return journey down a river. Water-tanks would be fitted."

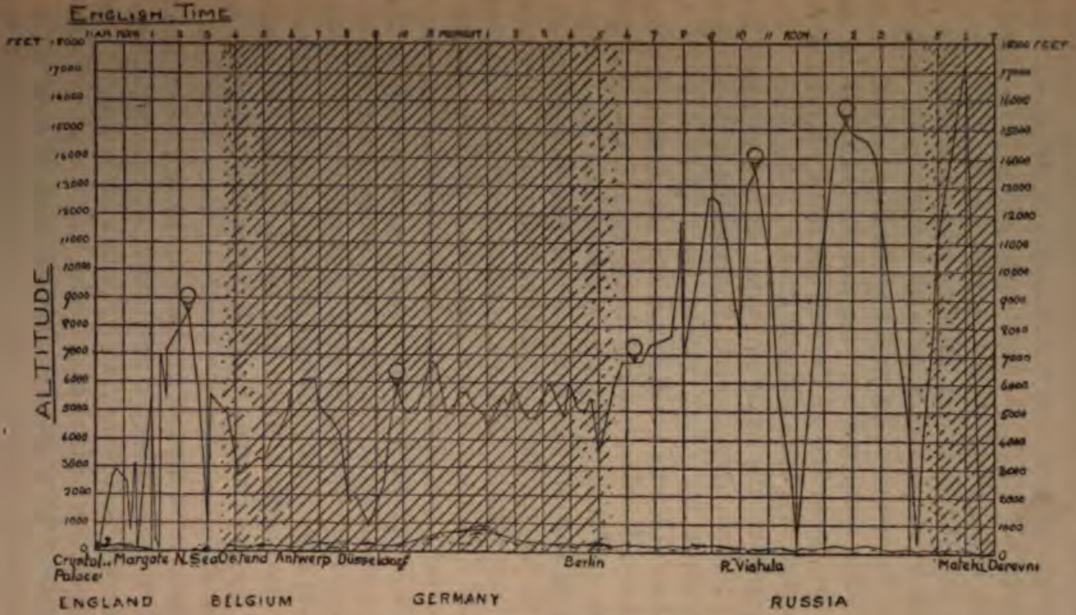


FIG. 8. LONDON TO RUSSIA BY BALLOON

In the summer of 1896 Andrée's preparations for an aerial dash to the North Pole were completed. On June 7 the party embarked at Gothenburg, arriving at Spitzbergen on the 21st. Andrée's scheme was to procure a suitable balloon and convey it with all necessary equipment, and the means of inflating it, as near the Pole as possible by ship, and then, with a favourable wind, to drift in the air across the region of the Pole until he should reach some inhabited land beyond it. The balloon was to be kept near the earth, and steered by means of the trail-ropes as far as practicable.

The balloon was made in Paris. It had a capacity of nearly 162,000 cubic feet. It was made with a special arrangement by which means the trail-rope could be shifted to different positions on the car, and it also had a rudder-sail, and an extra valve to prevent as far as possible any unnecessary loss of gas.

Andrée and his two companions, Nils Strindberg and Dr. Ekholm, finally selected Dane's Island as a suitable place from whence they might start their great voyage. By July 27 all was in readiness, and with the inflated balloon they waited for a favourable wind for the start. But after waiting for three weeks without any change of wind to the right quarter, the captain of the ship that had conveyed them and their equipment to the island said that they must return at once to avoid being frozen in for the winter. They had no choice but to return home, leaving the shed and gas-generating apparatus for another occasion.

On May 28 of the following year they started again for Dane's Island. Frankel and Svedenborg accompanied Andrée and Strindberg, as Dr. Ekholm had retired from the expedition. From May 30 to July 11 they waited, and then, with a wind somewhat west of south, they started on the ill-fated voyage. One or two messages came from Andrée by means of buoys which they threw will leave the balloon to the society folk who like to experience and make a sensation. We will leave the balloon to fashionable Saturday afternoon crowds at Hurlingham," said one ardent new disciple of aviation. The attitude was excusable, although it ignored certain very important facts.

Ballooning had, indeed, at its worst, been the mere showman's business, or a somewhat purposeless—albeit delightful and healthful—sport. But it should not have been overlooked that, even during the excitement caused by mechanical flight, France and Germany continued steadily to build military balloons, spherical as well as dirigible, whilst some notable projects for geographical exploration with the aid of balloons were put forward.

The balloon, since man first ventured to soar aloft, has been and will remain one of the principal methods of exploring the atmosphere, and undeniably the most pleasant. Ballooning is a delightful, health-giving pastime, in which the comparatively feeble and nervous can engage with impunity. It will continue to be the handmaiden of the sciences of meteorology and aviation, and, with the advance of mechanical flight and the increasing need to know and understand the laws of the aerial ocean, ballooning will increase in importance and value.

b. Principles

Balloons are vessels made of a special cotton fabric or of silk, varnished; or, more generally of late years, of rubber-treated fabric. They are inflated either with coal gas or with hydrogen, and they rise because these gases are much lighter than air. The first balloons were filled simply with hot air.

Hydrogen is the lightest of all gases, being about one-eighteenth the weight of air, although the hydrogen used in ballooning is never quite pure, and usually weighs about one-fifteenth as much as air. It is an elementary substance, and is without smell or taste.

In combination with air, hydrogen is highly inflammable and explosive, and it burns with a non-luminous flame of very high temperature. This quality is utilized in the hydrogen blow-pipe.

The danger of fire is the chief menace to airships, and elaborate precautions have to be taken to prevent the sparks from the motor coming into contact with escaping gas. This gives to lighter-than-air craft their particular weakness and vulnerability, and there is no means at present known of completely avoiding the danger. In the later Zeppelin airships, however, the space between the gas-containers and the outer case was filled by the inert gases discharged from the cylinders of the petrol engines. This promised a certain amount of protection, but failed to fulfil the promise, as was shown in the destruction of more than one of these craft by bombs.

Coal gas has, approximately, one-half the specific gravity of air. Its weight varies according to its degree of purity. The weight of the air, under different conditions of atmospheric pressure, varies also. But for ordinary ballooning we can assume that coal gas is half the weight of air.

A toy balloon containing ordinary lighting gas, which is not, as a rule, pure coal gas, but a mixture of coal and water gas of a very inferior quality for balloon purposes, will ascend into the air to a considerable height. Even this small amount of gas is sufficiently buoyant to lift the weight of the envelope which encloses it. And it will ascend until it reaches an altitude where the weight of the surrounding air is not more, volume for volume, than that of the gas plus the weight of the envelope. As a matter of fact, the toy balloon will almost certainly burst ere it reaches that height.

The respective weights of air and balloon gases are, in round figures, given here :

Air . . .	At sea-level (or Bar. 30" 60° Fahr.) 1000 cubic feet	75 lbs.
Coal gas .	At sea-level (or Bar. 30" 60° Fahr.) 1000 cubic feet	37½ „
Hydrogen.	At sea-level (or Bar. 30" 60° Fahr.) 1000 cubic feet	5 „

Hot air weighs less than cold air, and can, therefore, be employed as a lifting agent. Its advantages for ballooning would be overwhelming if by its means a big lift could easily be obtained, but in view of the fact that, in order to obtain an equal lift to that of coal gas, a temperature of 400° Fahr. would have to be maintained, hot air is for most ballooning purposes impracticable : the hot-air balloon must be of enormous relative bulk, and the difficulties of maintaining the temperature are great. The days of the Montgolfier balloon, however, are by no means past, and considerable promise is held out by a French contrivance for heating the air in the balloon by a compact and safe form of petrol stove, the heat from which can be easily regulated. By this or by some similar method it is hoped that reasonably long journeys will be possible, altitude being regulated by the amount of the flame.

The " buoyancy " of a gas is the difference between its weight and the weight of an equal volume of air. Knowing the approximate weight of each, it is easy to calculate the lifting-power, for practical purposes, of a given quantity of gas. A balloon of 10,000 cubic feet of hydrogen filled at sea-level in a temperature of 60° Fahr. has a lift of about 700 lbs., the difference between the weight of its gas and that of the air it displaces : of such a balloon the envelope, network, basket, and equipment would weigh nearly three hundredweight, leaving about 400 lbs. for aeronaut and ballast. The lifting power of a balloon of the same size filled with coal gas would be no mor than about 375 lbs.

A moment's reflection will show that even if a lighte gas than hydrogen were available the advantage would b small. Supposing such a gas weighed 1 lb. per 100 cubic feet as against the 5 lbs. of hydrogen, a gain o only 4 lbs. per 1000 cubic feet would be obtained, or 40 lbs in a 10,000 cubic feet balloon—a very small advantag even supposing the lighter gas were no more costly t produce, or that there were no countervailing disadvantage, such as greater liability to leak through th envelope.

The gross weight of balloon, passengers, and ballas are, just before the ascent, adjusted until it abou balances the weight of the air displaced. It is then i equilibrium, and on lightening its load the balloon wil rise from the ground and ascend to that level at which it weight again exactly balances that of an equal volum of the air surrounding it. The balloon leaves the groun lighter than air, and it ascends until it is of the same weigh as the air. The weight of the air, volume for volum steadily decreases with altitude. The bigger the "lift given to a balloon by discarding ballast the higher it wil ascend before it reaches equilibrium.

The neck of the balloon is opened before starting, s that the expanding gas will not burst the fabric. Durin the ascent gas pours out through the open neck of th balloon, which, however, remains fully inflated while i is climbing. The weight of the gas, although of the sam volume as at the start, diminishes; but so also does th weight of the surrounding air. The decrease is in th same ratio, and the lift, therefore, steadily diminishe For example, a 10,000 cubic feet balloon has a lift o 700 lbs. when it contains 50 lbs. of gas and displace 750 lbs. of air. On ascending to a height of 2,000 feet if the temperature is the same, the gas it contains and th air it displaces will weigh less by about one-fifteenth part in each case. The lift of the balloon will then be :

Air	750 lbs. less one-fifteenth	(50 lbs.) .	700 lbs.
Gas	50 lbs. ,, ,,	($3\frac{1}{3}$ lbs.) .	$46\frac{2}{3}$ lbs.
	700 lbs.	. . . . .	$653\frac{1}{3}$ lbs.

The figures given are only approximate, but they serve to show the principle. With every further increase of altitude there is a decrease of lift, and this decrease can be calculated by the simple process of estimating, first, the degree of expansion as indicated by the reading of the barometer, and then by reckoning the weight of a given volume of air and of gas and taking the difference, allowing also for temperature. Thus, the barometer at a height of 4,000 feet reads about 26 inches. Taking a 10,000 cubic feet hydrogen balloon, then, and basing the calculation on the fact that at 30″ Bar. and 60° Fahr. 10,000 cubic feet of air weigh 750 lbs. and 10,000 cubic feet of hydrogen weigh 50 lbs.—$\frac{10{,}000 \times 30''}{26''} = 11{,}500$, which is the volume to which the original 10,000 cubic feet, both of the air and of the hydrogen, will have expanded at 4,000 feet. The balloon has lost the odd 1,500 cubic feet of gas through the open neck, and the 10,000 cubic feet of gas that remain now weigh $\frac{10{,}000}{11{,}500}$ of 50 lbs. The air it displaces weighs $\frac{10{,}000}{11{,}500}$ of 750 lbs. The result is about 44 lbs. and 650 lbs. respectively, and the lift of the balloon has gone down to about 606 lbs.

Temperature affects the density of all gases, and therefore of the air, to the extent of $\frac{1}{500}$th part for every degree Fahr. Air at 40° Fahr. therefore weighs $\frac{20}{500}$ths more than at 60° Fahr. A balloon filled in low temperature has a bigger lift than if filled in warm weather : it contains heavier gas ; but the air it displaces is also heavier. On the other hand, if the low temperature occurs after the balloon has left the ground the effect is to contract the gas in the balloon, which becomes, therefore, of smaller volume, displacing less air and giving reduced lift. This causes the balloon to stop rising or, from equilibrium, to descend, until ballast is thrown out to restore the balance.

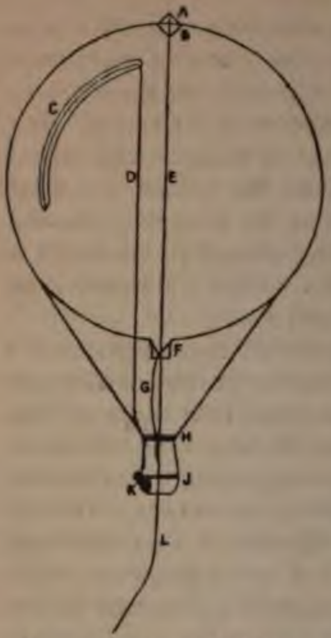


Fig. 9. Parts of a Balloon

A. The valve. B. The valve-springs. C. The ripping-panel. D. Ripping-cord. E. Valve-line. F. Neck. G. Neck-line. H. Hoop. J. Basket. K. Grappler. L. Trail-rope.

At the top of the balloon is a valve, opened by a cord which comes down through the neck into the car. This cord, when pulled, opens the valve inwards, and the gas streams out through the top of the balloon. When the pull is released the valve shuts with a snap, for it is strongly springed.

If the balloon at any time is in equilibrium in shadow, and then passes into warm sunshine, the gas expands and the balloon climbs to a higher altitude. Sooner or later the gas overfills the balloon, and some of it pours out through the open neck. If desired the climbing can be checked by opening the valve.

If the sun decline, or cloud is entered and the balloon receives a deposit of moisture from the mist, or if it rains, or if low temperature condenses the gas, the balloon descends, and it is necessary to throw out ballast if a continuation of the journey is desired. In many cases the discharge of a couple of handfuls of sand is sufficient to stop the descent.

Throughout the voyage a small quantity of gas is percolating through the fabric of the balloon. The voyage could continue indefinitely if it were not for waste of gas and expenditure of ballast. Sooner or later, however, comes the time when but little ballast is left, and a descent must be made. Then the aeronaut looks out for a good landing-place, and he may open the valve in order to descend at a given spot rather than be driven past it. On coming within a few yards of the ground he may pull open the "ripping panel," which is a large aperture in the side of the balloon near the top. It is lightly sewn up for the purpose of each voyage, but is easily torn open. By this means the balloon is deflated quickly, and a trouble that used to beset balloonists—that of being dragged along the ground in the wind by the slowly deflating balloon—is avoided. Sometimes the grapnel, or anchor, is used in landing.

Regard must be paid to atmospheric conditions if a long journey is desired, and since the utility of ballooning rests on the possibility of making long voyages, this requires a full knowledge of the technique of ballooning. When it is desired to make a long voyage, it is best to start at night, in order to avoid the sun's heat. At night a balloon usually keeps a steady equilibrium, and little ballast need be thrown away. The temperature is constant, and the gas does not expand and escape to any appreciable extent.

To fill a balloon with coal gas takes from three to five hours. To fill it with hydrogen supplied from tubes, in which it is stored in a state of great compression, less than one hour suffices. Hydrogen is nearly always used in military ballooning, the tubes being easily transported in wagons. It is often convenient to take a portable hydrogen-making plant into the field. For military purposes gold-beater's skin balloons are often used for captive ascents, because they retain the gas so well that they remain inflated, sometimes, for weeks. The cost of inflation with coal gas varies from £4 to £15, according to the size of the balloon. Roughly speaking, a balloon of 50,000 cubic feet capacity will take £5 10s. worth of coal gas. Hydrogen for such a balloon might cost about £25; but it is impossible to specify exactly the cost of hydrogen, which, as a by-product of certain manufacturing processes, should in some localities cost less than coal gas.

In the chapter on Navigation of the Air it will be explained that there is no motion in a balloon relative to the air. A balloon travels with the air. Its direction and speed can only be determined by the aeronaut by observing the ground below. When out of sight of earth, in clouds, or above them, it is impossible to ascertain the direction or the speed.

In addition to the ordinary winds from various points of the compass, there are upward and downward currents of air. An upward current chiefly affects the balloon through the loss of gas caused by its expansion in ascending to a greater altitude. With a downward current the gas condenses, and it is generally necessary to throw out ballast, in order to restore equilibrium. Usually in such cases the effect amounts to very little. It is different, however, when we consider the remarkable conditions sometimes set up by thunderstorms. Then a balloon becomes difficult to manage. It is alternately drawn upwards and swept downwards with embarrassing suddenness.

It is necessary to recognize that the balloon is completely at the mercy of the wind. True, there are occasions when the balloonist can, by ascending or descending into a different stratum of air, meet a different current and modify his direction, and even, on occasion, retrace his path, or make for some desired destination. But it is not often that much can be accomplished in this way, and the balloonist can never depend upon finding a favourable current.

As to the material of which balloons are made, cotton has one drawback, in that it is not the lightest material that can be used. That, of course, is gold-beater's skin, the cost of which puts it out of the question for nearly everything but military needs, where considerations of expense have to be sacrificed to the one aim of utility. Gold-beater's skin has for years been used by Great Britain in military balloons, but is now being supplanted by other materials. Silk is a very good fabric in point of lightness and gas-retaining capacity, but it soon deteriorates. A cotton balloon should stand three years' usage and still remain in good condition.

The cordage varies from the size of ordinary twine in the upper part of the net to that of a clothes-line, about a third of an inch in diameter, as it reaches the hoop, and runs therefrom to support the car. It should be of the best hemp. The necessity for strength is obvious when one remembers that the cordage has to support, in the larger balloons, a weight of more than a ton. The hoop is an important feature. Built of white ash in four separate rings, spliced together and strengthened by a steel core, it is almost impossible for it to break. The hoop is often made of wood, strengthened by steel cord wound round it.

The strength and durability of a balloon's basket and tackle have often been demonstrated in a startling way. In a gentle breeze they have come into contact with buildings and pulled walls over. The author took part in a descent in Russia in a gale, when the basket was hurled against a bank in a wind of sixty miles an hour, and although the shock was so violent as almost to stun the aeronauts, the basket simply bent to the strain, and it even endured a terrific drag over ground for half a mile without sustaining damage.

The trail-rope of a balloon serves a variety of purposes, its chief use being to preserve equilibrium at a low altitude. When it is trailing along the ground, any descent on the part of the balloon will result in a greater length of the trail-rope falling on the ground, thus relieving the balloon from so much of its burden. On the other hand, any slight ascending movement results in the lifting of some of the rope off the ground. The extra weight of this is thus borne by the balloon, whose ascent is checked to that extent. Prolonged voyages are often possible by the aid of the trail-rope. At night, and also when at sea, it enables the balloonist to ascertain his direction according to the compass. The direction in which the trail-rope drags out in contact with land or with water is, of course, the direction from which the wind is blowing.

Some small amount of dirigibility is obtainable with the use of the trail-rope, but so slight as to be of very little value. Its retarding effect on the balloon is very little, but just enough to enable the wind to be felt, when the balloonist, by setting up a sail, may steer a point away from the wind's course.

Sea-floaters, answering at sea the same purpose that the trail-rope serves on land, have been tried. One type is a cylinder with tapering ends. The two extremities are air-tight compartments, while the main body is hollow, but at one end is pierced with holes through which water readily pours. The tilt at which the floater travels can be regulated from above, so that the aeronaut can, at will, empty some of the water out of the floater or allow more water to pour in.

With the exception of small unimportant details of construction, and the introduction of the ripping panel, the balloon has, however, not made any progress for a century. It is incapable of being improved radically, except by the discovery of some means by which the gas could be retained indefinitely, or kept at an even temperature, enabling a balloon to remain in the air for a very long period.

CHAPTER IV

THE FIRST AIRSHIPS

IG after the invention of the steam-engine it was ıd possible to equip a balloon with mechanical power. year 1852 witnessed the first attempt to do this, experimenter being Henry Giffard, who built, in is, a spindle-shaped balloon, the length of which 130 feet. The power was provided by a 3 h.p.

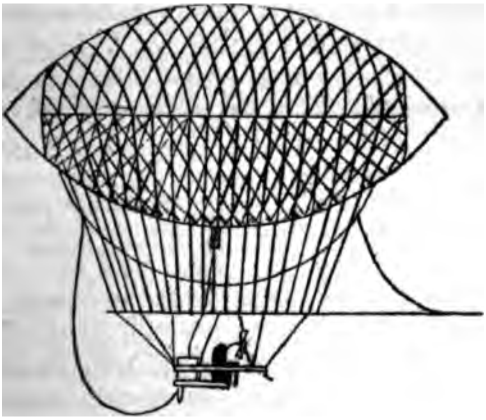


FIG. 10. GIFFARD'S BALLOON, 1852
The first airship driven by an engine.

m-engine. In still air this airship had a speed of four s per hour. Long before Giffard's time an egg-shaped oon had been projected by General Meusnier, who oduced the principle of the ballonnet. The Meusnier oon was to be equipped with hand-worked propellers rudder, an idea that was anticipated by the Brothers ert in 1784.

hroughout the early part of the nineteenth century various attempts were made to obtain dirigibility by hand-propelled machines, some with screw propellers, others with oars. But Henry Giffard was the "father" of the dirigible balloon.

From the earliest attempts to the beginning of the twentieth century very little progress was made: the Renard airship of 1884 was almost as good as the airship of twenty years later, except for the motive-power.

A list of the various projects during the eighteenth and nineteenth centuries is given here:—

The First Airships

Year.	Maker.	Particulars.
1784.	The Brothers Robert (France).	A fish-shaped balloon, 52 feet long. Steered by hand-oars. She was slightly steerable in calm air.
1812.	Leppig (Russia).	A fish-shaped balloon, with a fin-propeller. She was unsuccessful.
1834.	Count de Lennox (France).	A cylindrical balloon, 130 feet long, fitted with twenty oar-propellers. She proved too heavy, and was destroyed by disappointed onlookers.
1848.	Hugh Bell (England).	A cylindrical balloon, 55 feet long, with screw propellers. She was quite useless.
1852. and 1855.	Henry Giffard (France).	A spindle-shaped balloon, 236 feet long, with winged propellers and a 3 h.p. steam-engine: could deviate slightly from the direction of the wind. She burst during a landing.
1870.	De Lôme (France).	A spindle-shaped balloon, 110 feet long, with screws and sail-like rudder. She could deviate slightly from the direction of the wind.
1872.	Haenlein (Austria).	A cylindrical balloon, 165 feet long, with a 4-cylinder gas-engine of 2·8 h.p. A moderate success.
1883.	Tissandier Brothers (France).	A spindle-shaped balloon, length 90 feet. Driven by a Siemens electric motor with a bichromate battery.

ar.	Maker.	Particulars.
84.	Renard and Krebs.	A cigar-shaped balloon, 160 feet long, with a screw propeller, and a solid, pyramid-shaped rudder. She attained a speed of 7½ miles per hour.
86.	Woelfert (Germany).	Cigar-shaped, 91 feet long, with a two-bladed aluminium screw, and fitted with a Daimler benzine motor. She made four moderate trials, but ended with disaster and the death of two aeronauts.
93.	David Schwartz (Russia).	A rigid, aluminium airship, which proved useless.
95.	David Schwartz (for Germany).	A rigid aluminium airship, 150 feet long, with a separate steering-screw, but no rudder. Fitted with a 12 h.p. Daimler motor. She could make no headway against a 10-mile breeze, and after landing was destroyed by wind.
98.	Zeppelin (Germany).	A rigid airship, roughly cigar-shaped, 418 feet long, 399,000 cubic feet capacity, and fitted with two 16 h.p. motors. Successful when descending to water.
	Santos-Dumont (France).	A cigar-shaped balloon. Very successful. Won the Deutsch prize of £4,000.
00.	Roze (Colombo).	A double airship. Failure.
02.	Severo (Paris).	Non-rigid airship that exploded during trial flight, designer and engineer being killed (May 12).
	Bradsky Laboun.	A semi-rigid that broke up in the air (October 3).

In the present century the number has increased too pidly for any list to be made here.

If a traveller's strange tale is to be believed, Chinese ial enterprise ought to be included in the list. In illes du Génie de l'Homme," by Amedée de Bast, ated that Father Vassou, a missionary at Canton seventeenth century, speaks of a balloon which ascended at the coronation of the Empress Fo-kien in 1306. It is not impossible that something of the nature of an aerial vessel may have been actually employed at that time. This would be the less surprising since the writings of European philosophers of that period foreshadowed the efforts and expressed the longing of men to fly.

A French author fifty years ago was so desirous of crediting the Chinese with the conquest of the air that he described an imaginary aerostat, and convinced a large number of people that the Chinese had solved the problem. Delaville Dedreux relates in a curious book published in Paris in 1863 that in the year 1860 he voyaged from Fout-cheou to Nant-chang in this balloon. He states that the Chinese possessed an intimate knowledge of air-currents, by which they were able to choose their aerial paths. A great number of observatories sent up small captive balloons from high towers, and the direction of the wind at various altitudes was reported to the navigator of the air. The intelligence was conveyed all over the Empire by an elaborate system of signalling. Above the clouds the Chinese aeronauts kept their bearings by means of a compass. The sausage-shaped vessel was kept even with the current of air by a retarding influence at the stern, acting as a drag, this being simply a screw operated by manual labour. It is to be remembered that in those days the Chinese often served the

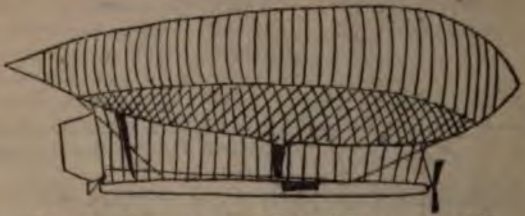


FIG. 11. RENARD AND KREBS' BALLOON, 1884

Driven by electricity. The first airship for which success can reasonably be claimed.

purposes of the fiction writer in the same way that Martians are used by modern novelists.

By the year 1905 the dirigible balloon had become established. The Zeppelin, the Parseval, the Lebaudy, the Baldwin, and the Gross, even the dilatory British military dirigible, were the topic of the day, until the newspapers grew weary of what was no longer even a mild sensation. Airship factories sprang up. Governments began to project airships in secret.

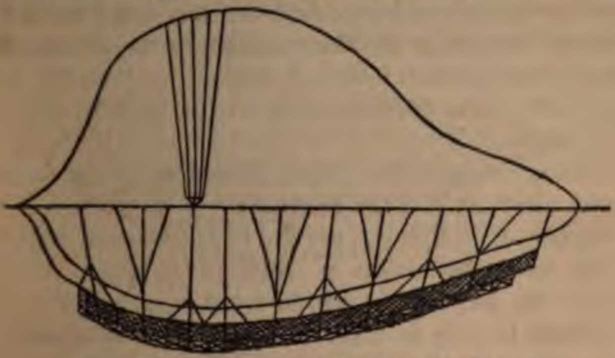


FIG. 12. LEPPIG'S BALLOON, 1812
It was to be driven by a fin propeller, worked by hand.

The principle of the dirigible balloon was condemned by some authorities, notably Sir Hiram Maxim, who wrote as follows in the *Times* of February 26, 1908. The letter is quoted here extensively because it sums up the arguments usually used by those who did not believe in the dirigible balloon. In view of the achievements of the Zeppelin and other airships, Maxim subsequently modified his opinion slightly, and even made suggestions in the design of dirigible balloons; at the same time he has never wavered in his belief that the future lies in heavier-than-air machines.

"Take that triumph of engineering skill, the 'Nulli Secundus,'" wrote Maxim. "The gas-bag, which was sausage-shaped and 25 feet in diameter, was a beautiful piece of workmanship, the whole thing being built up of gold-beater's skin. The cost of this wonderful gas-bag must have been enormous. The whole construction, including the car, the system of suspension, the engine and propellers, had been well thought out, and the work beautifully executed; still, under these most favourable conditions, only a slight shower of rain was sufficient to neutralize its lifting effect completely—that is, the gas-bag and the cordage about this so-called airship absorbed about 400 pounds of water, and this was found to be more than sufficient to neutralize completely the lifting effect. A slight squall which followed entirely wrecked the whole thing, and it was ignominiously carted back to the point of departure.

"The gas-bag of the 'Nulli Secundus II' is sausage-shaped, and 42 feet in diameter; it is provided with an engine of 100 h.p., which, it is claimed, will give to this new production a speed of 40 miles an hour through the air, so that with a wind of 20 miles an hour it will still be able to travel 20 miles an hour against the wind. The cylindrical portion of the gas-bag is 42 feet in diameter; the area of the cross section will therefore be 1385 feet. If we take a disc 42 feet in diameter, and erect it high in the air above a level plain, and allow a wind of 40 miles an hour, which is the proposed speed of the balloon, to blow against it, we should find that the air pressure would be 11,083 pounds—that is, a wind blowing at a velocity of 40 miles an hour would produce a pressure of 8 pounds to every square foot of the disc. Conversely, if the air were stationary, it would require a push of 11,083 pounds to drive this disc through the air at a rate of 40 miles an hour."

Maxim proceeded to demonstrate that to attain this speed it would be necessary to have a motor of 1181 h.p., but as the end of the sausage-shaped balloon was not flat, but rounded, the horse-power might be somewhat less. To drag this balloon along by means of a steam-engine running on rails would take 236 h.p. —" that is, assuming that the gas-bag would stand the strain. But the engine is to be carried in the balloon, and it is to act by means of air-propellers which work with a great waste of energy—not less than 50 per cent of the horse-power being lost. Therefore the balloon would require a motor of 472 h.p."

Undisturbed by the striking occasional successes achieved by dirigible balloons, Maxim "stuck to his guns." And when all the world was hailing Zeppelin and the Brothers Lebaudy as the conquerors of the air, he prophesied that disaster would, sooner or later, overtake every one of their airships. The fact is worth recalling that while the public were reading Maxim's prophecy of disaster, Zeppelin's airship was wrecked in precisely the manner that he had foretold, namely, by a gust of wind after its descent.

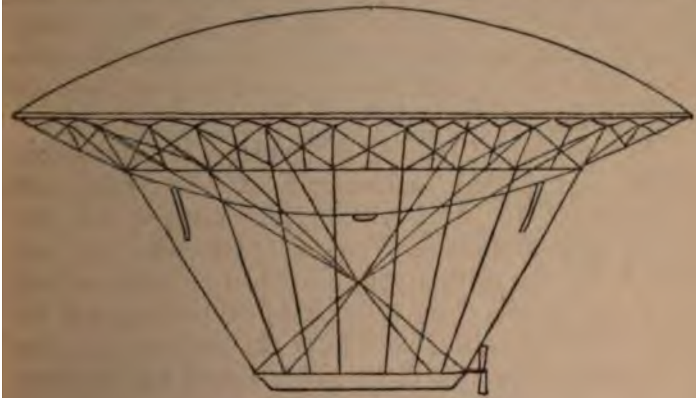


FIG. 13. DE LÔME'S AIRSHIP

In an interview in the *Observer*, Maxim said:

"I cannot see any future for the dirigible, which, from its very nature, will always be powerless against the wind. The dirigible, like the spherical balloon, can little more than drift helplessly with the wind. Re

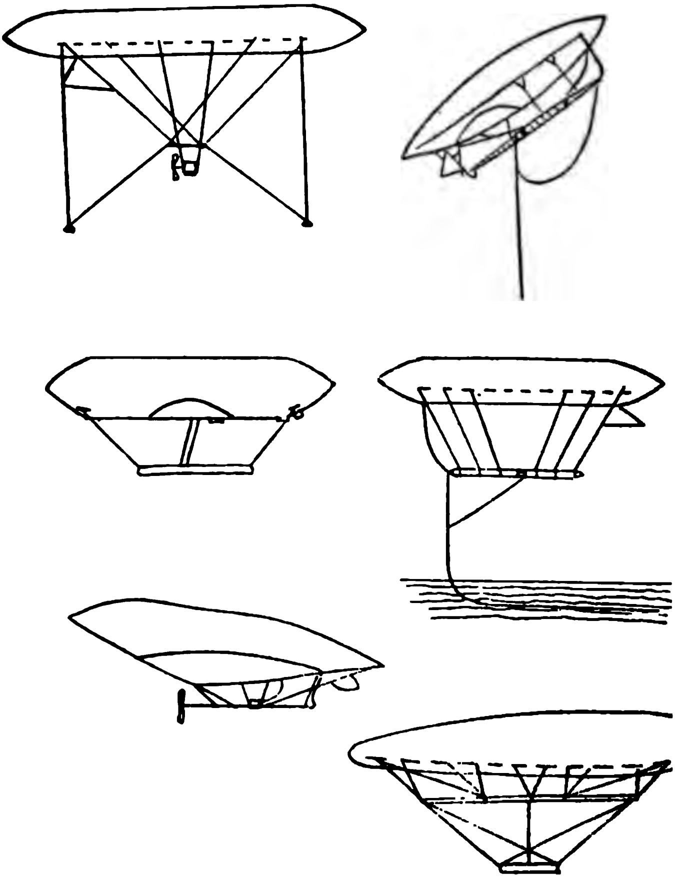


Fig. 14. Santos-Dumont's Airships

Showing some of his principal designs and how they developed. The bal at the bottom on the right is the most advanced type shown.

tively to the air which it is to navigate, the dirig as the jelly-fish is to the sea. It is no more resis that, and is just as much at the mercy of ever

d eddy. Hydrogen gas is the most evasive substance
control. The Zeppelin balloon must have leaked at
e rate of, say, 1000 feet per hour. As the gas escapes
m a balloon, the envelope sags in and forms a pocket
on which the wind has enormously increased power.

“To prevent this the Zeppelin balloon was made of
number of gas-containing balloons, enclosed in an
uminium outer case. But the rigidity of this outer
velope depended partly upon the inflation of the bal-
ons inside. As they lost gas, the resisting-power of the
uminium case became less. When you consider that
e whole apparatus had to be lighter than a correspond-
g volume of air, you will realize that it could not be
ry strong. With no material known to science could it
strong enough. Indeed, we should have to discover
mething as light as cork, yet three times as strong as
eel, before we could have a satisfactory dirigible balloon.
the same time, we should require some substance which
uld be absolutely impermeable by hydrogen.

“An effort has been made to secure rigidity by means
the ballonnet, as used in the French balloons. This
a small balloon inside the hydrogen bag. As the
drogen escapes out of the envelope air is pumped into
e empty ballonnet, distending it, and thereby filling
the space and distending the outer envelope. But,
r obvious reasons, this is a very poor compromise, and
ly of extremely limited use. The air pumped into the
llonnet is as heavy as the surrounding atmosphere,
d the necessary apparatus also is so much additional
ight to carry.”

The problems before the dirigible balloon concern
ength, stability, and equilibrium. Powerful engines
n be taken up—that is only a question of lifting-power,
e size of the balloon; but if the balloon is driven
yond a certain speed it will not bear the strain. Hence
e introduction of the rigid type.

One of the most famous airships of the rigid type was Zeppelin No. 4, which was destroyed when making a twenty-four hours' trial trip down the Rhine. It was about seven times as big as the first British airship, being 426 feet long and 42 feet in diameter, and having a capacity of 455,000 cubic feet. It had a rigid aluminium framework, containing seventeen separate compartments filled with hydrogen. A sliding weight was employed to preserve balance. It was fitted with two cars and four three-bladed propellers, and planes for steering up and down.

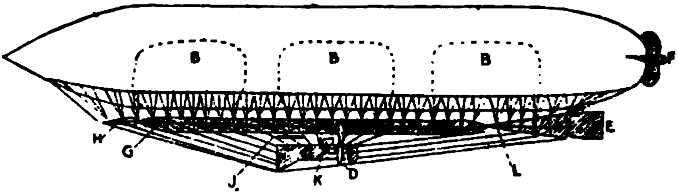


FIG. 15. THE LEBAUDY SEMI-RIGID AIRSHIP

B. Ballonnets. C. Car. D. Propeller. E. Rudder. F. Stabilizing planes. G. Rigid frame. H. Front adjustable plane. J. Horizontal plane. K. Petrol reservoir. L. Rear adjustable plane.

The non-rigid type consists of a fabric envelope, inflated to such an extent as to be almost rigid, or provided with special appliances preventing flabbiness. The non-rigid balloon cannot, of course, avoid at times suffering reduction of bulk through passing into low temperatures and from other causes, and when flabby it cannot be driven at more than very low speed owing to increased air resistance.

The first British airship was of this type. This balloon, which was wrecked during a trial trip, measured 120 feet long and 25 feet in diameter, and was driven by an eight-cylinder 50 h.p. motor. There were two propellers, driving the vessel at something like twenty miles an hour in still air.

In order to have a gas-container that would be or less proof against the filtration of the gas through the fabric, combined with strength sufficient to allow of tightness in inflation, the War Office went to the expense of a gold-beater's skin (one of the membranes of the ox) envelope. This envelope was composed of about fifteen layers of skin, to provide which it is reckoned that no fewer than 200,000 oxen must have contributed. The joining together of all the pieces entailed a prodigious amount of labour. Between the layers of skin a certain amount of silk thread was used, this item alone costing £30. It is reckoned that the complete envelope cost more than £2000. And it is doubtful, even if that particular type of airship had proved itself at all comparable in point of efficiency with the French and German types, whether it could have been made in sufficient numbers.

Various methods have been devised for taking tucks in an airship's envelope when it becomes flabby, or for refilling the bag during flight; but not one of these devices is satisfactory.

General Meusnier, as long ago as 1784, realized the difficulty and suggested a gas-envelope surrounded by a space for air, enclosed in an outer envelope. When the space between the two envelopes was filled with air, the weight of the air would be so much added to the burden of the balloon, reducing its lift. It would also compress the gas-envelope, condensing the gas, and thereby further checking the lifting-power. In order to obtain ascensive power, the aeronaut would simply pump air out of the air-cover and allow the gas-balloon to expand.

The ballonnet now in general use is an air-pocket contained within the gas-envelope (see p. 69 and Chapter XIII).

Among the non-rigid types was the "Ville de Bordeaux," built by Surcouf, and adopted by the French army. This was one of the noteworthy series, "Ville de Paris," "Clement-Bayard," and others. The gas-envelope of the first of these was 170 feet long and 47 feet in diameter, and held about 100,000 cubic feet of gas. The engine was an 80 h.p. four-cylinder Renault. In front of the car was a triplane elevator, having a surface of 560 square feet, and behind was a double rudder for steering. Stability was to some extent provided for by a group of four pear-shaped gas-bags surrounding the rear end of the main envelope.

A compromise between the rigid and non-rigid types was the Lebaudy, a form of airship held by some authorities to be superior to the Zeppelin. In this type the gas-envelope rests in a keel or bed of metal tubing.

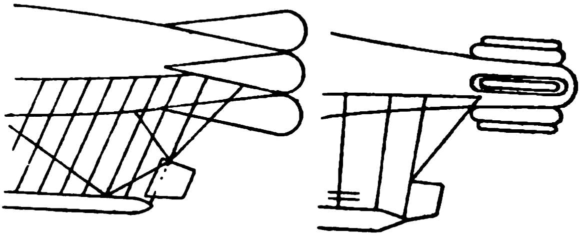


Fig. 16. Two Styles of Empennage at the Stern for Keeping Stability

It is necessary to refer here to a hybrid class of airship —a combination of airship and aeroplane, which is very slightly heavier than air. This was devised by M. Malécot, but in some respects Malécot's work was anticipated by Barton in England and by some earlier designers. The Malécot airship consisted of a spindle-shaped gas-envelope, 100 feet long, 24 feet in diameter, and of a capacity of 36,900 cubic feet. Suspended beneath it by a number of ropes was an aeroplane 63 feet in length. The planes were inclined at a greater upward tilt than is usual in aeroplanes. The 30 h.p. motor was fitted into a sort of cage, where there was also sufficient r for a pilot and a mechanic. The propeller cons of a single piece of wood strengthened with metal, measured about 11 feet in diameter. Below the aeroplane was a basket which could carry a weight of 600 lbs. for giving greater stability and for adjusting the aeroplane at different inclinations as required. The balloon was provided with a ballonnet. In making an ascent the aeronaut adjusted the aeroplanes, so that when the motor was started and the propellers revolved the planes had a forward, upward, gliding motion. The advantage of a mixed airship of this description was supposed to consist in the fact that less gas was needed, and that, in case of accident, the aeroplane would be able to continue its flight alone for some distance, and make a safe landing.

In the early days of the modern dirigible balloon a journey of 100 miles was remarkable. The voyage of "La Patrie," of 160 miles, in October, 1907, was hailed as a great achievement, and the Zeppelin journey round Lake Constance, a distance of 200 miles, in the same year, electrified the world. Zeppelin, however, soon followed with journeys of 270, 360, and 900 miles. The longest journey at this period was forty hours, and the highest not more than 5000 feet. But these achievements, ordinary as they now seem, were promising enough to cause great activity in the designing and building of military dirigible balloons.

In spite of all difficulties, dirigible balloons capable of an independent speed of 20 to 26 miles per hour had been made in considerable quantities. In the air they were, when properly made, perfectly safe. Their principal danger was in descending to the ground in a high wind. Then their enormous area gave great resistance to the wind, and they were very apt to be "buckled," and even to be hurled over and destroyed by gusts. With these limitations the dirigible balloon appeared, nevertheless, a machine of great possible utility.

CHAPTER V

THE FIRST AEROPLANES

In 1893 Clement Ader made a full-sized steam-driven flying machine with flapping wings, but subsequently turned it into a monoplane, and on October 14, 1897, in the presence of representatives of the French War Minister, he flew 300 metres. He relates that the surprising experience nearly caused him to lose his senses. The machine was wrecked in landing. The spectators would not, or could not, induce the authorities to take the matter seriously, and Ader's invention was ignored until, in the enthusiasm caused by practical flight achievements in 1908, it was remembered and placed in the Aeronautical Exhibition at the Grand Palais in December of that year.

In his disappointment at the coldness of its reception in 1897 Ader burned all the drawings, and would have destroyed the machine but for the solicitations of a friend who appealed to him on the ground of patriotism.

Lawrence Hargrave, an Australian, in 1898 and 1899, made some remarkable experiments with kites, and invented the cellular or box-kite. The principal experimenters in kites who made ascents were Le Bris in 1856, Baden-Powell in 1894, Wise in 1897, and Cody. The Farman and the first Santos-Dumont aeroplanes were based on the principle of the Hargrave box-kite.

Owing in very large measure to the promise afforded to aviation by the introduction of the light petrol motor, progress became rapid. It renewed men's hopes, for early experimenters, like Maxim, had said, "Give us a light and powerful engine, and we will show you how to fly."

In 1900 Wilbur and Orville Wright, of Dayton, Ohio, achieved better results than Chanute or any other predecessors. They made gliders having twice as great a lifting surface as that hitherto employed. In their first gliders the aviators took a horizontal attitude. The work of the Wright Brothers is stamped upon aeronautics, and it is not necessary here to describe their experiments in detail. They attained extraordinary skill and experience in flight. They made almost daily ascents during many years, keeping aloof from observation, and allowing it to be supposed that the rumours of their exploits were merely newspaper sensationalism. Not until 1908 did these famous pioneers fly in public.

Ernest Archdeacon, in France, obtained some valuable results in 1905; and in February, 1905, in conjunction with the Aero Club of France, he held an exhibition of gliding apparatus and models of flying-machines. Esnault-Pelterie at the same period was also making gliding experiments in France. But it will be sufficient to mention here a few of the more famous record flights at that interesting period in the history of aviation.

It was on September 13, 1906, that Santos-Dumont made the first officially-recorded European aeroplane flight, leaving the ground for a distance of twelve yards. On November 12 of the same year he remained in the air for twenty-one seconds, and travelled a distance of 230 yards. These feats caused a sensation, but comparatively few people realized that a new and wonderful era was being ushered in.

An Englishman deserves the credit for the next flight, although he made it in France on an entirely French machine. This was Henry Farman, who, on October 26, 1907, flew 820 yards in fifty-two and a half seconds, and quickly followed with other flights. on July 6, 190 remaining in the air for twenty and a half minutes. Lé Delagrange also was at this period making flights.

These experiments, however, were eclipsed in Ameri by the Wright Brothers. Orville Wright accomplish a flight of over an hour's duration as long ago as Septe ber 9, 1908, and on September 12 stayed up for one ho and fourteen minutes. Then Wilbur Wright went France and began his remarkable series of flights, oft taking up passengers with him. Half-hour and even ho flights were very common: and on December 31 Wilb

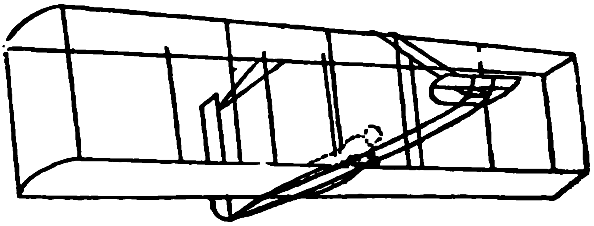


FIG. 17. WRIGHT'S GLIDING APPARATUS

This differs from Chanute's and others in having no tail or "stabilizer."

Wright flew for two hours and nineteen minutes, a all the world wondered. Wright also demonstrat that pupils could become adept after spending a fe hours in the air; and his pupils in their turn becan teachers.

To Farman belongs the distinction of making the fir cross-country journey in an aeroplane. On October 3 1908, he flew from Chalons to Rheims, a distance sixteen miles, in twenty minutes.

From one achievement to another aviation mad progress until, slowly, the public began to think th was "something in it" after all. France was in ad of England in this respect, playing her usual rôle of pioneering. France's record, as in the industry, resulted in her taking the cream of the aerial motor and aeroplane industries, and securing a lead of many years.

In England nothing was done at all comparable with the achievements of the French and the Americans. S. F. Cody, A. V. Roe, and two or three others were doing pioneer work, but the public took no interest. Roe made the first flight in a British machine, Cody following closely with his biplane. Towards the end of 1908 Moore-Brabazon bought a Voisin biplane, in which he made short flights in France.

Meanwhile, in Canada, Douglas McCurdy was making significant progress, and achieving results which compel us to place him next to the Wrights, who at that time had no serious rival. The "Silver Dart" in which McCurdy made his trials resembled the Wright machine in that it had no tail. The supporting surfaces had only a single concave curvature. In various respects it resembled the Wright machine, having the elevator in front and the vertical rudder at the rear, but it was driven by only one propeller. McCurdy made many demonstrations with his apparatus, and flights of half an hour were frequent. The Canadian Government were so impressed that they decided to afford official help. McCurdy was assisted by Baldwin, who made flights in the same apparatus.

Dr. Alexander Graham-Bell was experimenting on a totally different type of machine. This was called the "Cygnet II," and it consisted of some 3500 tetrahedral cells. A small measure of success was achieved, but it was spoilt by accidents.

In the United States Glenn Curtiss constructed a biplane which, in some respects, resembled the Wright machine, and with it won laurels at the Rheims Aviation Meeting.

The Aeronautical Society of Great Britain, in 1908, obtained a ground for experiments at Dagenham, near London, and the Aero Club opened an aerodrome in Sheppey.

At the close of the year the first great Aeronautical *Salon* was held in Paris, when upwards of a dozen full-sized machines were exhibited. London followed suit three months later with an even more important exhibition. The Paris exhibition was crowded every day; the London Aero show failed to draw the British public. Schools of aviation were opened, and scores of officers of the French army could at this time ascend in aeroplanes under the guidance of Delagrange or of Wilbur Wright. At Göttingen University lectures on aeronautics began, and steps were taken in Germany and France to found chairs of aeronautics. Boys adopted the making of model aeroplanes as a new pastime, discarding old-fashioned toys.

Early in 1909 the British Government appointed a permanent Aeronautical Committee to investigate problems arising out of the practical work being done by naval and military aeronauts. A special department was organized at the National Physical Laboratory at Teddington. The members first appointed to the Committee were Lord Rayleigh, Dr. R. T. Glazebrook, Major-General Sir Charles Hadden, Captain R. H. S. Bacon, Sir A. G. Greenhill, Dr. W. N. Shaw, Horace Darwin, R. H. A. Mallock, Professor J. E. Petavel, and F. W. Lanchester. The appointment of this Committee, although long-delayed, showed that Great Britain was convinced of the practicability of flight.

Aviation is the direct successor to motoring, the self-propelled carriage having been rendered practicable by the invention of the internal-combustion engine, in its commonest form the petrol motor. The inventor of the internal-combustion engine was Fernand Forest, who died from the effect of shock due to an accident in the motor-boat which, with his son, he was navigating on a speed trial at Monaco in April, 1914.

This inventor in 1881 made his first motor, a vertical gas-engine. In the following year he designed an explosion motor, and in 1888 brought out a four-cylinder engine which embodied the main points of the motor-car engine. Through lack of means, however, he was unable to carry his work to a profitable conclusion: others enjoyed the fruits of his labours, and, indeed, it was not until 1911 that his work was recognized and he was awarded the Cross of the Legion of Honour.

It is interesting now to recall some of the prophecies of scientific men relating to flying. Benjamin Franklin is said to have commented on the first balloon ascents ever made with the remark, "Of what use is a new-born babe?"

In 1896 Lord Kelvin declared in a letter that he had no faith in aerial navigation other than ballooning, and he declined to become a member of the Aeronautical Society.

Lord Rayleigh, on November 29, 1908, in his address to the Royal Society, said:

"I cannot abstain from including in the achievements of the year the remarkable successes in mechanical flight attained by the brothers Wright, although the interest is rather social and practical than purely scientific.

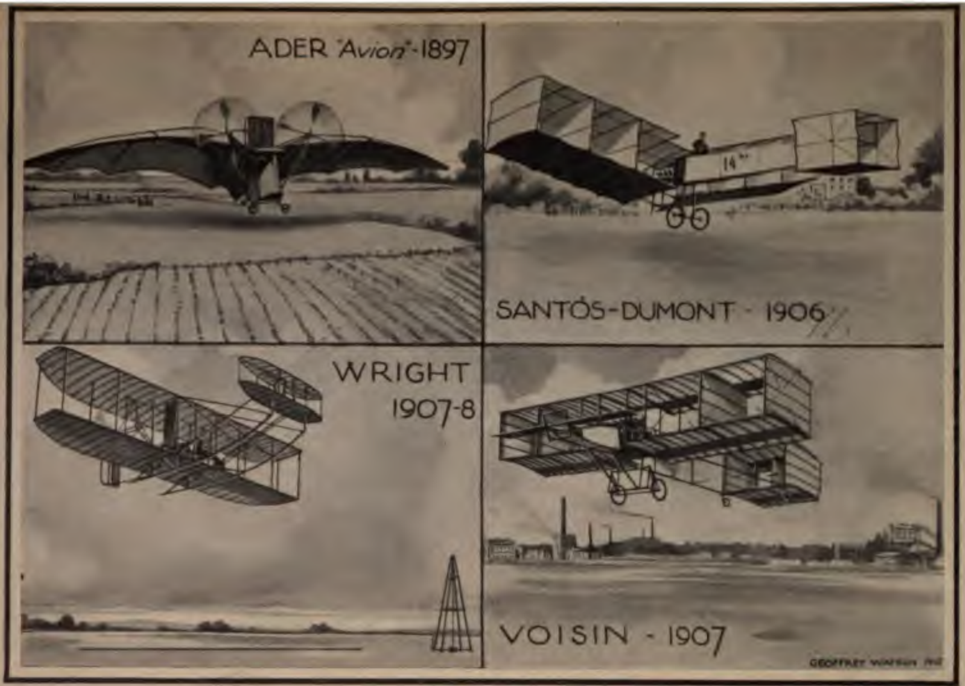
"For many years, in fact ever since I became acquainted with the work of Penaud and Wenham, I have leaned to the opinion that flight was possible as a feat. This question is now settled, and the tendency may perhaps be to jump too quickly to the conclusion that what can be done as a feat will soon be possible for the purposes of daily life.

"But there is a very large gap to be bridged over; and the argument urged by Professor Newcomb and based on the principle of dynamical similarity, that the difficulties must increase with the scale of the machin goes far to preclude the idea that regular ocean servic will be conducted by flying machines rather than by ships.

"But, as the history of science and invention abundantly proves, it is rash to set limits. For special purposes, such as exploration, we may expect to see flying machines in use before many years have passed."

In January, 1907, the British Secretary for Wa refused to enter into negotiations with the Wright Brothers, saying: "I have nothing to add to my last letter to you. The War Office is not disposed to ente into relations at present with any manufacturer o aeroplanes."

First flights on aeroplanes were made in the differen countries in the following order. (See opposite page.)



"The Aeroplane"

FOUR PIONEERS

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Date.		Country.	Name.	Machine.	Place.
1897	Oct. 17	France	Ader	"Avion" m.	Satory.
1903	Dec. 19	U.S.A.	Wright	Wright b.	Kitty Hawk, N.C.
1906	Sep. 12	Denmark	Ellehammer	Ellehammer	Sindholm.
1908	May 26	Belgium	H. Farman	Voisin b.	Ghent.
	May 27	Italy	Delagrange	Voisin b.	Rome.
	June 8	England	A. V. Roe	Avro b.	Brooklands.
	July 18	Holland	Lefebvre	Wright b.	The Hague.
	Oct.	Scotland	Lieut. Gibbs	Dunne b.	Perthshire.
	Nov. 24	Germany	Zipfel	Voisin b.	Berlin.
1909	Feb. 23	Canada	McCurdy	"Silver Dart" b.	Baddeck, N.S.
	July 25	Russia	Van der Schrouff	Voisin b.	Odessa.
	Aug. 3	Sweden	Hansen	Voisin b.	Stockholm.
	Oct. 17	Hungary	Blériot	Blériot m.	Buda-Pesth.
	Oct. 23	Austria	Blériot	Blériot m.	Vienna.
	Oct. 30	Roumania	Blériot	Blériot m.	Bucharest.
	Nov. 1	Algeria	Metrot	Voisin b.	Algiers.
	Dec. 2	Turkey	Baron de Caters	Voisin b.	Constantinople.
	Dec. 9	Australia	Defries	Wright b.	Sydney, N.S.W.
	Dec. 15	Egypt	Baron de Caters	Voisin b.	Abbassia.
	Dec. 28	South Africa	Kimmerling	Voisin b.	East London.
	Dec. 31	Ireland	Ferguson	Ferguson b.	Hillsborough.
1910	Feb. 2	Switzerland	Engelhardt	Wright b.	St. Moritz.
	Feb. 10	Spain	Mamet	Blériot m.	Barcelona.
	Dec. 17	India	Pecquet	Humber m.	Allahabad.
1911	Feb. 9	New Zealand	V. Walsh	H. Wright b.	Papakura.
	Feb. 21	China	Vallon	Sommer b.	Shanghai.

CHAPTER VI

THE AERIAL OCEAN

SAFE and useful flight depends largely upon a thorough understanding of the atmosphere, and it is surprising how slowly the knowledge of this subject progressed until the end of the nineteenth century. Then, owing to the attention given to aeronautics, and also owing to the desire to ascertain some means of controlling rainfall and preventing fog, men ventured beyond the very primitive investigations and speculations that had before contented them. In France systematic observations by means of kites and *ballons sondes* were carried on for many years, whilst little or nothing was being done in England. It was, however, an Englishman, Douglas Archibald, who first conceived the idea of sending up kites equipped with automatic registering instruments.

Height above Sea-level.	Temperature, ° F.	Humidity, Per Cent.	Wind Direction.	Wind Velocity, Miles per Hour.
1,100 feet	54	86	S. by E.	14
2,000 "	51	100	S.	30
3,000 "	50	85	S.-W. by S.	32
4,000 "	53	35	S.-W. by S.	36
5,000 "	52	30	S.-S.-W.	25
6,000 "	51	30	S.-S.-W.	—
7,000 "	48	25	S.-W. by S.	—
8,000 "	46	25	S. by W.	—

Weather: Fine, bright, sunny, moderate steady breeze.
Clouds at 2000 feet.

Early in the present century the Manchester University Meteorological Department commenced systematic kite observations, and the results have been invaluable. A specimen of the daily report issued for many years by this institute is given here. The report illustrates the very interesting phenomenon, common in the Northern Hemisphere, of the prevalence of more westerly winds in the upper air than at the earth's surface. Wise, the balloonist, declared that at an altitude of 15,000 feet he invariably met a westerly wind, and other aeronauts have observed this. The matter will be found further elucidated on page 95.

A series of ascents by free balloons and kites during a week in the summer of 1908 resulted in some interesting observations. For that week an international committee had organized a large number of ascents, the observations extending over a vast area. The French, German, and Italian Navies sent special vessels to the neighbourhood of the Canary Islands and the East Coast of Africa to participate in the work. On land, observations were made from stations distributed over Europe, America, Africa, and Asia.

The following figures bring out the details of these ascents:

1908	Time of Ascent.	Barometer.	Temperature, Ground Level.	Lowest Temperature Recorded.	Maximum Height Attained.	Place where Found.
			° F.	° F.		
July 28	8.32 p.m.	30·407 in.	54	−72	45,000 ft. (8½ miles).	Near Derby, 90 miles S.-E.
July 29	8.29 p.m.	30·411 in.	57	−81	55,000 ft. (11 miles).	Near Nottingham, 66 miles E.-S.-E.
July 30	5.10 p.m.	30·321 in.	60	−11	24,000 ft. (4½ miles).	Near Lincoln, 60 miles E. by S.
July 31	8.00 p.m.	30·334 in.	64	−58	56,000 ft. (11 miles).	Great Staughton, Hunts, 110 miles S.-E.
August 1	8.15 p.m.	30·325 in.	58	−66	57,000 ft. (11 miles).	Bicester, Oxon, 120 miles S.-S.-E.

From Manchester and Glossop six balloons were sent up, and of these only one was not recovered. The others fell at distances ranging from 50 to 120 miles, being returned from Derby, Nottingham, Lincoln, Huntingdon, and Oxford respectively. The greatest height attained was 57,420 feet, or nearly eleven miles.

It is of interest to note, as will be seen by the table above, that the temperature in that lofty region fell to −81° Fahr.—that is to say, to what popularly would be called 113° of frost, or 113° below the freezing-point. This is almost exactly the same as the lowest temperature ever recorded on the earth's surface. Captain Amundsen reported in 1905 a temperature of −79° Fahr. in Boothnia (North Canada), and temperatures as low as −75° Fahr. and even, it is said, −85° Fahr. have been registered at Verkhoyansk and Yakutsk, in Siberia.

The minus sign used in regard to the lowest temperatures —as, for example, −81° Fahr. on July 29—indicates below the Fahrenheit zero, which is 32° Fahr. below freezing-point.

"One has been accustomed to consider the atmosphere simply as a mass of air, decreasing in density with its altitude, but otherwise uniform," wrote C. S. Rolls, describing one of his flights. "Experience on a power driven flyer, however, shows that, far from this being the case, the atmosphere near the earth's surface—even in what we call calm weather—is made up of spiral movements of varying diameter, sometimes vertical and sometimes horizontal, undulations of all kinds—little hills and valleys, and streams of air. One might, in fact, speak of it as a new 'world' conquered by man—a world with scenery of great variation, which though invisible to the eye, is none the less felt by the operator of a flying-machine. To maintain equilibrium and steering control while battling with these complex movements of the air has been the great problem which for centuries has baffled human ingenuity. Side-winds and spiral currents can, of course, be avoided to a large extent by flying at high altitudes, but the disturbing currents near the ground have to be encountered before landing."

The wind, whether a light breeze or a strong gale, blows in a series of gusts of varying velocities. Thus, a wind averaging twenty miles an hour may vary within the space of a few seconds from calm to forty miles an hour. The accompanying diagram, which represents the actual velocities recorded by Professor Langley with an anemometer, illustrates the fluctuations of a wind whose mean was twenty-four miles an hour; it will be seen that in the third minute the wind fluctuated between thirty miles and zero.

Wind is broken up by hills, buildings, and other obstacles, but sometimes these wind irregularities are met at a great height, so that it appears likely that there are atmospheric causes of gusts. Lateral deviations also occur and in some cases the wind veers 20 or 30 degrees. There are complications also of slanting and even vertical currents upward and downward, due to hills, irregularities of temperature and other causes. Warm air rises and cool air descends, and where the surface of the land is of different radiating quality, or where land adjoins the sea, the air is in a constant commotion, seeking uniformity. Some of the commotion takes the form of eddies.

Upward currents and eddies are at times very violent, as proved by the lifting of great masses of water in waterspouts, by the unroofing of buildings, and by the lifting of heavy objects high up into the air.

Irregularities may be caused in high altitudes by two layers of air moving in different directions, when air waves are formed. "Aeronauts," wrote the Rev. J. M. Bacon, "looking down on the wind-swept surface of the clouds have observed these surfaces to be thrown into a

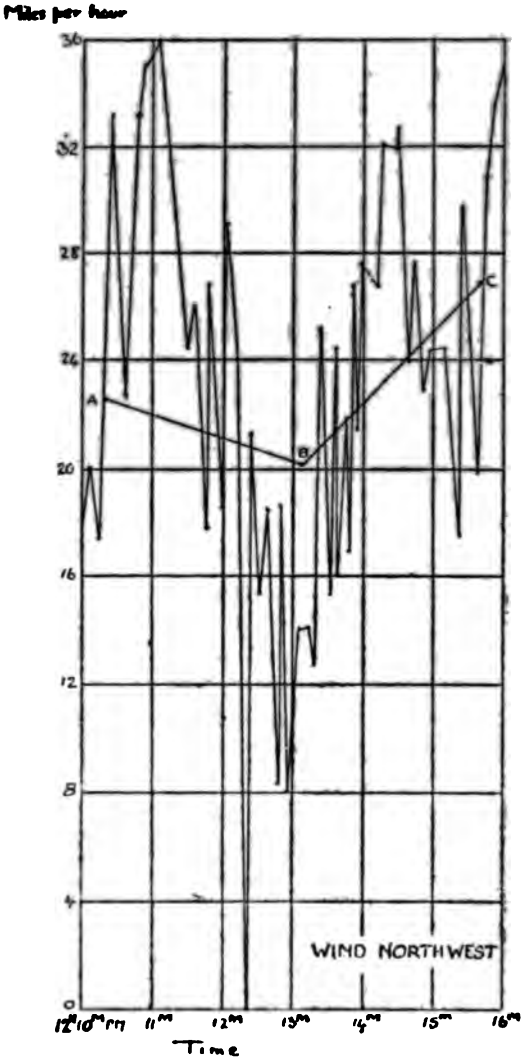

Fig. 18. A Wind Chart showing Gusts

series of rolls of vapour which are but vast waves of air. The interval between the successive crests of these waves has been estimated at half a mile."

An elementary fact about the atmosphere is that the temperature of the air decreases with the height up to what is known as the isothermal layer. At 40,000 or 50,000 feet the temperature increase ceases. The greatest height at which the thermometer has been directly read is 35,433 feet by Berson and Süring, on July 31, 1901, when the thermometer temperature was observed to be 38° Fahr. below zero; but an unmanned balloon sent up to a height of about 82,000 feet registered 94° Fahr. below zero, and Professor A. L. Rotch in the United States obtained a record of −110° Fahr. In a manned balloon sent up on December 4, 1894, at a height of 30,000 feet the temperature was 54° Fahr. below zero.

The following table, which was made at Berlin, shows the rate of decrease in the temperature at various heights. For more exhaustive information the reader is referred to the important works mentioned below.[1]

Height in Kilometres.	Mean Temperature, °C.	Decrease per 100 Metres, °C.
0	10·1	0·50
1	5·4	0·50
2	0·5	0·54
3	−5·0	0·53
4	−10·3	0·64
5	−16·6	0·69
6	−24·2	0·66
7	−29·4	0·72
8	−38·3	0·90
9	−46·4	—
Mean	—	0·63

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[1] "The Structure of the Atmosphere in Clear Weather," by C. J. P. Cave, M.A. (University Press, Cambridge.)

"The Free Atmosphere in the Region of the British Isles," by W. H. Dines, B.A., F.R.S. (Blue Book.)

It will be seen that at increasing altitudes the rate of decrease in the temperature on an average becomes greater. But, roughly speaking, the temperature decreases about 1° every 300 feet. In India the rate of decrease in the lower strata of the atmosphere is much more rapid, amounting to 1° in the first 33 feet. But it is only about 1° in 330 feet at an altitude of 15,000 feet.

In the upper strata of the air the temperature does not vary so much between the summer and winter as it does at the earth's surface, and between the temperature of the tropical and frigid zones there is but little difference at a certain altitude. Mountains in the tropics are snow-capped just as are mountains in the north or the far south, although the "snow line" is at a higher altitude in the tropics. If we made a balloon voyage round the earth at an altitude of 5000 feet we should find the average temperature fairly even. Over the equator it would be about 65° Fahr., and over London it would be about 40° Fahr., but the seasonal and the daily changes would be very much less marked than on the ground.

Another vital factor in the making of conditions that affect the aeronaut is humidity. The air contains a certain amount of moisture which may or may not be visible. Its visibility in the form of fog is determined by certain laws. A cubic foot of air at zero Fahrenheit can hold but half a grain of vapour, but at 60° Fahr. it can contain 5½ grains. At 80° Fahr. eleven grains can remain invisible in the same volume. When air can hold no more vapour, it is "saturated." When not "saturated," it can be rendered so simply by cooling, for cool air retains less vapour than warm air. When very warm and moist, a very slight cooling produces cloud and, finally, rain. Clouds are, therefore, more easily formed in warm countries than in cold, though other conditions may make clouds more common in cold countries.

Clouds are formed up to a height of 35,000 feet, but seldom higher than 25,000 feet. There are a series of elevations at which cloud formations are more frequent than at others. Thus the principal cloud regions are at the heights of 1600 feet, 6500 feet, 13,000 feet, 21,000 feet, and 35,000 feet, and the altitudes about midway between these are more frequently cloudless. Sometimes the cloud strata are of great thickness, banks of 3000 feet and 4000 feet of dense clouds being frequently met with. Then the aeronaut over a small island such as Great Britain has reason for anxiety. He has no means of locating his position. He must not remain out of sight of land for long.

The following table gives a general idea of the varieties of clouds and their corresponding heights, beginning with those near the surface.

Height in Feet.	Name.	Description
Sea-level up to 3,000.	Stratus.	Elevated fog, so called.
4,500 to 6,000.	Cumulus.	Rounded heap.
4,500 to 24,000.	Cumulo-nimbus.	Tower-like clouds, with round tops and flat bases.
6,400.	Strato-cumulus.	Rolls of dark cloud.
6,400.	Nimbus.	Masses of dark formless cloud.
10,000 to 21,000.	Cirro cumulus.	Fleecy cloud, mackerel sky.
27,000 (average height).	Cirro-stratus.	Fine whitish veil, giving halos round sun and moon.
27,000 (average height).	Cirrus.	Isolated feathery white clouds.

Space will not permit the inclusion of an explanation of cyclone and anticyclone, and the author would only counsel the reader to consult the latest works on this subject and not to accept theories that are now old-fashioned. So far as the subject concerns the airman disporting himself in the bottom 10,000 feet of atmosphere, it may be said that in the interior of a cyclone the air has an upward motion, which causes it to cool rapidly. Sooner or later, according to the amount of vapour in the air, clouds form and rain occurs. An anticyclone is just the reverse, for the air has a descending motion, becoming, in consequence, warmer, and causing the clouds to disappear, or, rather, the vapour to become absorbed invisibly in the air.

The higher regions of the air—speaking here not of the actual "upper air," but of the first 4000 feet—would be colder than they are if it were not for warm air rising from the earth. But air becomes warmer if compressed and its temperature falls when it is enabled to expand. The process in the atmosphere is akin to that by which hot water from the kitchen boiler is conveyed through pipes to the cistern at the top of the house. A constant change is going on, the relatively warm air near the surface of the earth always ascending. In some cases a portion of the water it contains becomes visible, forming clouds, rain, or snow, while the very cold air is constantly descending to take the place of the rising column of warm air.

"I have noticed," wrote Maxim in his work on "Natural and Artificial Flight," "a considerable degree of regularity in the movement of the air, especially at a long distance from land, where the regularity of the up-and-down currents is, at times, very marked. On one occasion, while crossing the Atlantic in fine weather, I noticed, some miles directly ahead of the ship, a long line of glassy water. Small waves indicated that the wind was blowing in the exact direction in which the ship was moving, and as we approached the glassy line, the waves became smaller and smaller until they completely disappeared in a mirror-like surface, which was about 300 or 400 feet wide and extended both to the port and starboard in approximately a straight line as far as the eye could reach. After passing the centre of this zone, I noticed that small waves began to show themselves, but in the exact opposite direction to those through which we had already passed, and these waves became larger and larger for nearly half an hour. Then they began to get gradually smaller, when I observed another glassy line directly ahead of the ship. As we approached it, the waves again completely disappeared, but after passing through it, the wind was blowing in the opposite direction, and the waves increased in size exactly in the same manner that they had diminished on the opposite side of the glassy streak. This, of course, shows that directly over the centre of the first glassy streak the air was meeting from both sides and ascending in practically a straight line from the surface of the water, and then spreading out high above the sea, setting up a light wind in both directions."

Santos-Dumont relates a ballooning experience in an upward current. "I let the balloon come down again," he writes, "hoping to find a safe air-current and when within 300 yards of the ground near the Var I pulled the valve open and let out more gas. But I could not go down. I glanced at the barometer and saw that I was ascending. I was being lifted up by an enormous column of air rushing upward. It became necessary to save all the gas I could, and I abandoned the attempt to descend. I was dragged up to a height of 10,000 feet, and was compelled to await the course of events."

Ordinary weather lore must be discarded when the mind approaches aerial navigation, for ordinary weather lore takes into account only those air-currents which sweep along the surface of the ground. The whole question of bird-flight and bird-soaring was a sealed book until investigation proved the existence of constant rising currents of air. The soaring of birds is believed to be possible only when the air is in motion. Directly there is a calm the bird descends, or is compelled to flap its wings. It should be stated, however, that all authorities do not attach much importance to vertical currents of air. Professor Langley attributes the hovering and sailing of birds to an intuitive adjustment by the bird to certain rapid changes in the speed of the wind. When a strong gust comes, the bird slides down to meet it, and, overcoming the back drift by his forward momentum, is able to utilize it simply for lifting him to the same height as he was before. When the lull comes he lies flatter, and can, therefore, be sustained by a diminished pressure of air. The reader is referred to some remarks by the author on page 108.

Darwin, in the "Voyage of the *Beagle*," said:

> "When the condors are wheeling in a flock round and round any spot, their flight is beautiful. Except when rising from the ground, I do not remember ever having seen one of these birds flap its wings. Near Lima I watched several for nearly half an hour, without taking off my eyes; they moved in large curves, sweeping in circles, descending and ascending without giving a single flap. As they glided close over my head, I intently watched from an oblique position the outlines of the separate and great terminal feathers of each wing, and these separate feathers, if there had been the least vibratory movement, would have appeared as if blended together; but they were seen distinctly against the blue sky."

The practical importance to aeronauts of knowing all about the winds, their causes and velocity, is evident. Just as the Admiralty employ a hydrographer, so it will soon be necessary to establish a permanent department of research and information concerning the movements of the air, not only at the earth's surface, but in the upper air also—not merely a bureau for use during war. The daily weather reports will be modified to suit the requirements of the flying-man. Perhaps in the far future weather bulletins will be on the lines predicted by Rudyard Kipling in a story in which he pictures life on the earth in the far future. Here is a sample weather bulletin:

"The northern weather so far shows no sign of improvement. From all quarters come complaints of the unusual prevalence of sleet at the higher levels. Racing planes and digs alike have suffered severely—the former from unequal deposits of half-frozen slush on their vanes, and the latter from loaded bows and snow-cased bodies.

"As a consequence, the northern and north-western upper levels have been practically abandoned, and the high flyers have returned to the ignoble security of the 300, 500, and 600 feet levels. But there remain a few undaunted sun-hunters who, in spite of frozen stays and ice-jammed connecting-rods, still haunt the blue empyrean."

Mr. W. H. Dines urges aviators to become familiar with the weather charts issued by the Meteorological Office. In these weather charts places of similar barometric pressure are joined together by lines called isobars, and the wind usually blows in a direction parallel to these lines. The distance on the chart between these lines is an indication of the variation of pressure over different regions. If the lines be close to each other, it is clear that the variation is great, and what is known as a steep gradient exists.

The following table gives the gradient wind velocity in miles per hour, corresponding with the distances in inches and parts of an inch between the consecutive bars drawn on the working charts issued by the Meteorological Office every day, and it will be found that the velocity of the wind at a height of from 1000 to 4000 feet agrees fairly well with this calculation. The isobars are drawn for each 0·1 inch. The table is calculated for a pressure of 30 inches; temperature, 50° Fahr.; latitude, 52°.

Distance between isobars in inches.	Gradient Velocity (in miles per hour).
0·1	223
0·2	112
0·3	74
0·4	56
0·5	45
0·6	37
0·7	32
0·8	28
0·9	25
1·0	22
1·1	20
1·2	19
1·3	17
1·4	16
1·5	15
1·6	14
1·7	13
1·8	12½
1·9	12
2·0	11
2·2	10
2·5	9
3·0	7

The direction of motion may be taken as parallel to the isobars. In the Northern Hemisphere an observer, standing with his back to wind, has the region of lowest pressure on his left hand.

The increase of wind velocity with increased height is most important to the aerial navigator. Near the beginning of the present chapter a day's report of kite observations at Manchester was given illustrating this. Here is another specimen showing increase of wind strength at the higher altitude, which, indeed, is a common feature of these reports.

Height above Sea-level in Feet.	Temperature, ° F.	Humidity, per Cent.	Wind Direction.	Wind Velocity, Miles per Hour.
1,100	56	85	S. by E.	10
2,000	57	75	S. by W.	23
3,000	55	70	S.S.-W.	25
4,000	54	75	S.-W.	24
5,000	47	80	S.-W.	26

Weather: Fine, bright, warm; gentle steady breeze.

Approximately the winds in seventy-five cases per cent ow a turning to the right in the upper air. Between heights of—

o and	3,000 feet	the deviation	to the right is	15	degrees
000 ,,	6,000 ,,	,,	,,	13	,,
000 ,,	10,000 ,,	,,	,,	11	,,
000 ,,	13,000 ,,	,,	,,	1	,,
000 ,,	16,000 ,,	,,	,,	3	,,
000 ,,	19,000 ,,	,,	,,	6	,,
000 ,,	22,000 ,,	,,	,,	6	,,

otal twist of 55 degrees in about four miles; so that, example, a south wind on the ground becomes a uth-west wind at a height of four miles. Under certain nditions of the weather, deviations from these figures turally occur, and sometimes there is a twist in the posite direction, i.e. to the left when ascending.

Observations of cloud movements by Clayton at Blue ll Observatory, near Boston, U.S.A., give some in- esting data.

Cloud Level.	Height in Feet.	Average Speed. Miles per Hour.
Stratus	1,676	19
Cumulus	5,326	24
Alto-cumulus	12,724	34
Cirro-cumulus	21,888	71
Cirrus	29,317	78

Taking an average of the surface winds throughout year, the late Professor Loomis found the following erage velocities for the wind:

	Mean Velocity of Wind. Miles per Hour.
Europe	10·3
United States	9·5
Southern Asia	6·5
West Indies	6·2

In Britain the average surface wind is nearer twelve les an hour. The surface wind varies with distance m the sea, with the time of year, and with the time of y.

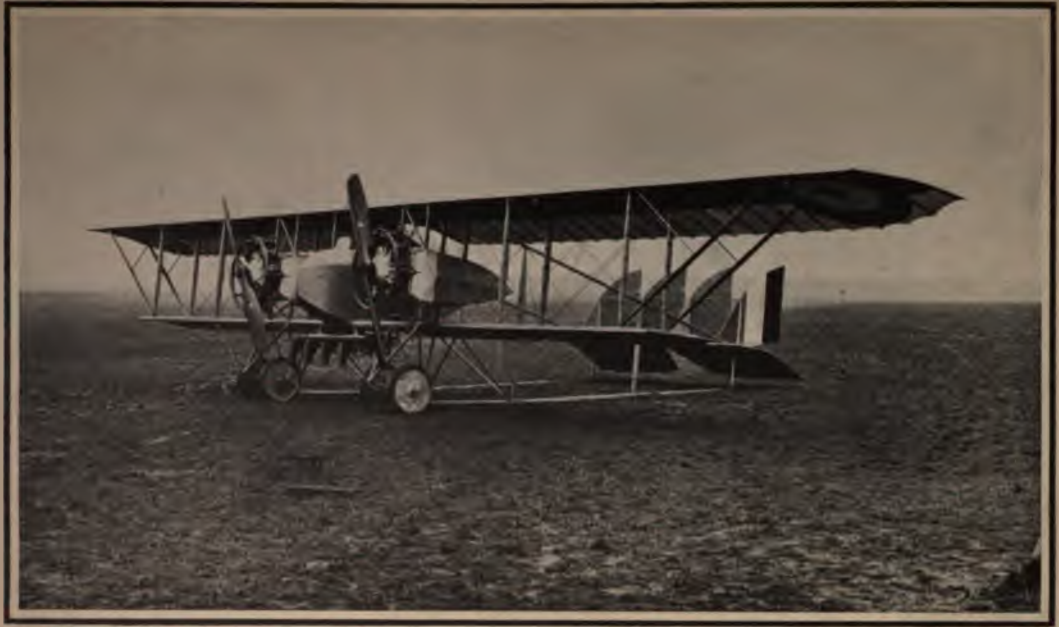
The general circulation of the atmosphere, due to the divisions of temperature between poles and equator, and the distribution of land and water, greatly affects local disturbances. We have in the Northern Hemisphere, between the equator and latitude 35 degrees, prevailing north-east winds, and in the Southern Hemisphere prevailing south-east winds. But at great heights in the Northern Hemisphere the winds are south-west, and in the Southern Hemisphere they are north-west. At the equator, with its ascending masses of warm air, we get heavy clouds and rain, but a calm zone at the earth's surface. Above, however, an east wind will be found, and as we go north of the equator this becomes a north-east wind.

In latitude 35 degrees, whether north or south, we have a calm zone. In the upper air in the Northern Hemisphere south-west winds prevail, which with increased altitude, owing to the rotation of the earth, become more westerly.

The general distribution of the wind is shown by the table constructed by Hann:

Geographical Latitude.	Wind on Surface of Earth.	In the Middle Strata, 10,000 to 32,000 Feet.	In the Upper Strata, above 32,000 Feet.
60° N.	W.-S.-W.	W.-N.-W	W.-S.-W.
30° N.	N.-E.	S.-W.	W.-S.-W.
10° N.	E.-N.-E.	E.	E.-S.-E.
Equator:			
10° S.	E.-S.-E.	E.	E.-N.-E.
30° S.	S.-E.	N.-W.	W.-N.-W.
60° S.	W.-N.-W.	W.-S.-W.	W.-N.-W.

The great speed attained by balloons when only light breezes are blowing on the surface of the ground shows what aeronauts must be prepared to contend with. There are instances on record of speeds of over 100 miles per hour. J. Simmons travelled at a rate of nearly 120 miles per hour on one occasion. A. E. Gaudron once travelled



F. N. Birkett *Shepherd's Bush, W.*

THE BRITISH CAUDRON BIPLANE

An example of the double-engine machine.

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110 miles in just over one hour, ascending in a high wind from the Alexandra Palace and descending near Spalding.

In an article by Mr. W. H. Dines, the author gives the following useful general data. The particulars refer to England, but hardly differ from those obtained on the Continent. "At the earth's surface the mean density of the air is such that one cubic foot of it will weigh one and a quarter ounces, but, owing to the changes in the temperature and in the height of the barometer, this value may be increased or decreased by some 10 per cent. The mean annual temperature in England is close to 50° Fahr. At a height of one mile the density will be about 82°—if we take 100° to represent it at sea-level—and the temperature rather over the freezing-point. At two miles the density is about 66° and the temperature about 20° Fahr. At five miles, and this is about the limit that man has ever reached, the density has sunk to about 35° and the temperature to a value that will probably be between $-20°$ and $-60°$. Up to five miles there is certain to be a steady decrease of temperature, but, somewhere between five miles and nine miles high, a point will be reached beyond which the temperature will cease to fall. The usual height of this point is seven miles, and the usual temperature is from $-50°$ Fahr. to $-70°$ Fahr.; but the temperature may be as high as $-40°$ or as low as $-90°$ Fahr. At about fifteen miles our knowledge from direct observations ceases, but at this point the density is reduced about $3\frac{1}{2}$ on the scale, and barely $\frac{1}{30}$th of the whole atmosphere remains above. The temperature probably is about $-60°$ Fahr.

"At sea-level in England the barometric pressure may easily vary from 29·00 to 30·50 inches. This is equivalent to a change of 1500 feet in altitude.

"At night, calm mostly prevails in the lower strata if the sky be clear; and this is particularly the case on frosty nights—and even days, too—in winter."

The terms "air-pocket" and "hole in the air" are frequently heard in flying circles. The terms are not very felicitous since they give many people an impression of an absolute emptiness, or relative emptiness, in the atmosphere, and an aeroplane tumbling over the brink of it and falling uncontrollably to the bottom, there, if lucky, to be cushioned on sound air again. Nothing quite like that exists, although a machine does in certain circumstances suddenly drop a few feet, and even as much as a couple of hundred feet, and the aviator then experiences a sinking sensation figuratively described first, the author believes, by Léon Delagrange as like "falling into an air-pocket."

What produces that effect, which is very common, is usually a lull in a head wind. On encountering a lull a machine is momentarily deprived of some of its support; there is a sudden diminution in the strength of the rush of air, and the machine falls, usually to be quickly buoyed up again by the succeeding gust, or by a downward plunge gaining speed and thus recovering support. Another cause might be emergence from an up-current into level air.

All these conditions are commonest when the sun is creating temperature disturbances in the air, after rain or frost, or when shining through rifts in dense cloud. Vice-Admiral H. King-Hall's despatch describing the destruction of the German cruiser *Königsberg* states that on occasion, even on calm days, British naval airmen had violent fluctuations of altitude of as much as 250 feet.

These conditions are disquieting even to experienced aviators, and they test a machine's structural soundness.

The old idea was that an air-pocket was a vacuum, or something very much like it; and here a most interesting passage in "Paradise Lost" may be recalled. This extract, although containing a reference to a "vacuity," shows that Milton had an extraordinarily vivid alization of the need of the support of the air to flying reatures, even to the Prince of Darkness himself. Albeit n “ air-pocket ” eleven or twelve miles deep is not likely be encountered except, conceivably, during such ataclysms as that of the great eruption at Krakatoa.

> “ At last his sail-broad vanes
> He spreads for flight, and in the surging smoke
> Uplifted spurns the ground ; thence many a league
> As in a clouded chair ascending rides
> Audacious ; but, that seat soon failing, meets
> A vast vacuity : all unawares
> Flutt'ring his pennons vain plumb down he drops
> Ten thousand fathom deep, and to this hour
> Down had been falling, had not by ill chance
> The strong rebuff of some tumultuous cloud
> Instinct with fire and nitre hurried him
> As many miles aloft.”

From the following table the reader will be able to stimate the number of days in a year on which an erial vessel of any given speed would be navigable. The able applies to Paris, where the atmosphere is somewhat almer than that of London.

Speed of the Wind in Kilometres per hour.	Number of Days in one Year when there would be a possibility of Wind being less than that of the first column.
9	39
18	117
27	197
36	258
45	297
54	323
63	342
72	350
81	354
90	358
99	361
108	363
117	364
126	364
135	364
144	365
153	365
162	365

782090

Eddies are found over every pool and river due to the cooling effect of water on the air above it. An aviator by observing the country over which he is flying can anticipate these disturbances, but some eddies are produced by causes invisible from above. Save to the novice an eddy is not very embarrassing. Its effect upon an aeroplane is to cause it to oscillate or roll in certain well-defined ways. Every aerodrome has its own particular eddies and some that are constant have their special names. For example, on Salisbury Plain over a well-known wood near the flying-ground at Larkhill, there is an eddy known as "Aunt Sally," which is found in all weathers and at all times. Wind has the effect of bending the invisible whirlpool aside so that the precise point at which the eddy may be met varies slightly according to the direction of the wind. When considerable quantities of water exist at a very little depth below the surface of the ground, the aviator cannot always observe the difference between the damp earth and dry ground, yet he will almost invariably find the air over it in a disturbed condition.

Groups of trees cause eddies owing to their coolness as compared with the open country, and these eddies are sometimes felt at a great height as well as those caused by ponds and rivers. They are also found over white roads, chimney-stacks, and moving trains.

The atmosphere provides an almost inexhaustible series of phenomena affecting flight. Very little is known as to the cause of the accumulation of electric potential which finds vent in lightning discharge. Almost everyone who has flown a kite with a wire has experienced slight shocks of electricity even under a cloudless sky. At Aldershot two soldiers handling a military kite were knocked down by the violence of the electric discharge. Observation of atmospheric electricity shows that the air is electrified at all times, storm or no storm, and also that the distribution of electric density is far from being uniform. In fair weather the potential of the air—the normal potential, as it is called—is usually positive, its numerical value increasing with distance from the ground. In Great Britain the rise is about fifty volts per foot, but steeper gradients are not uncommon. In warm, dry countries the rate is higher. At a certain height increase ceases.

Aeronauts have had remarkable experiences during thunderstorms. A. E. Gaudron and E. M. Maitland, caught by a thunderstorm while ballooning, made a descent after being much driven about by contrary winds near Sevenoaks. They observed that all terrestrial noises were suddenly silenced by the intervention between them and the earth of a thundercloud. This was before the thunder began. It is often observed that clouds act as conductors of sound, and balloonists testify that the barking of dogs and the rumble of trains are heard more distinctly when a cloud intervenes.

The echoes obtainable from a balloon are extremely curious. At times they are of value as a means of measuring the distance from the earth, by taking count of the time the sound takes to return. A shout is flung back from the house-tops or the land with startling distinctness. The Rev. J. M. Bacon, who made many scientific ascents accompanied by P. Spencer, recorded the fact that the echo is invariably a trifle later than the exact distance should make it. He fired a charge of gun-cotton 100 feet below the basket of his balloon, and it sounded more like a pistol shot than the ear-splitting crash he expected. The cause, he explained, is that the sound expends itself in the air.

CHAPTER VII

NAVIGATION OF THE AIR

AFTER men made the first boats, and ventured on what was then the mysterious and terrifying ocean, it was long before they trusted themselves out of sight of the friendly land, or essayed to discover other shores. It was as great a step, although not so long in taking, from the first feeble human flights to extensive cruises in the air.

When man made the first boats he did not foresee the evolution of the modern liner or battleship. His imagination was so unexercised that probably he never desired much greater mastery of the sea than was afforded by his rough-hewn craft. With very different mien has man approached aerial navigation. With the making of the first balloon came dreams of complete mastery of flight. With the achievement of actual flight in a heavier-than-air machine came the sure knowledge that in a little while men would explore the air freely and safely.

But in the early days, when flying men kept close to earth and never ventured up after sunset, and before a dirigible balloon had sailed for a night or descended safely in darkness, little attention was given to the question of the navigation of the air. "Let us learn to fly first," said man; "we will learn aerial navigation in due time."

Ordinary ballooning provided some material for the foundation of the science of aerial navigation; it afforded a clearer realization than would otherwise have been possible of the need of the aeronaut who, provided with a dirigible balloon or aeroplane, desires to make a prolonged voyage. Experience gained during long balloon voyages and even the records left by men who have projected great aerial expeditions are valuable.

In one important respect the navigation of the air by machines of any sort whose direction can be wholly or partially controlled is, of course, very much easier than ordinary ballooning. In the latter case the aeronaut is at the mercy of the currents of the air. He can only hope to ascertain his whereabouts, and to descend rather than run into danger.

Let us first of all try to understand the difficulties of aerial navigation as faced by the ordinary balloonist. One of the principal problems is the difficulty of ascertaining direction during the night or when above the clouds. It is hard, perhaps, for the person who has never been in a balloon or a flying machine to understand this. In daytime, and when the earth is in sight, it is comparatively a simple matter, with the aid of the compass, to take the line of a balloon's course. At night, if no fixed lights on the earth be visible, or if the balloon be over the sea, it is impossible. The compass-needle points to the north, but the aeronaut has no means of ascertaining the direction the balloon is taking. And it is equally impossible in daylight when above the clouds; for the clouds may be moving in the same direction as the balloon, or in some totally different direction. Only if one could be quite sure that they were stationary would it be possible to ascertain the direction.

Rightly to understand the problem, it must be remembered that a trail-rope hanging from a balloon free in the air travels with the balloon. It does not drag out behind it. Indeed, if the end of the rope should be caught in a different current of air, it might be blown out to the left or the right of the balloon's course. But nothing is certain, and therein lies the balloonist's difficulty. The balloon travels with the air; it may be going at sixty miles an hour, but relatively it is in a calm. The balloonist does not feel the slightest air-movement. Dropping articles out of the balloon gives no indication of the direction. If the aeronaut lets fall a ball of paper, no matter if he is travelling at fifty miles an hour, the paper is not left behind, but appears to fall directly downwards, keeping below the moving balloon throughout its fall. At night, again, it is impossible to tell one's direction by observing the stars. The basket of a balloon is frequently moving round and round, sometimes so slowly as to be imperceptible, but nevertheless moving. During a night journey in which the author took part it was comparatively easy to recognize the course over England, from London to Yarmouth, because the night was fine and there were frequent land lights visible. By these and the compass it was possible to make the direction, to draw a line on the map, and then to look for any large towns near which that line passed. Some uncertainty remained in spite of these aids, for there were long periods when no lights were in sight; but Harwich and Yarmouth were recognized by their shape with fair certainty. When land was passed and the balloon drifted out over the North Sea, we were quite ignorant as to direction, except that there was reason to feel confident that the same wind held out. So dark was the night that the sea was not visible, but at dawn a large steamer was seen, and by observing the angle it made with the compass-needle, and by noticing the line the course took with respect to it—as a matter of fact, the balloon passed over its wake at right angles—we again got an approximate course. In spite of the assurance this gave that the course was still north-east, the first sight of the Danish coast was exceedingly agreeable.

In another all-night journey the conditions were totally different. Localities were easily recognized, but n the early hours of the morning thick fog came on. Descending and putting out the trail-rope, so that it dragged along the invisible ground pulling away from the basket, gave an indication of the course.

Many of the difficulties disappear with the use of efficient aircraft with motive-power. In the case of an airship, provided everything is in order, it may be assumed that the vessel is making some headway. But here a difficulty arises. There is always some movement of the upper air—seldom less than a breeze of twenty miles an hour. A dirigible balloon, therefore, making for some definite point must often make an oblique line towards it, just as a ferry-boat crosses a swift-flowing stream. At night, or oversea, or above the clouds, it is in scarcely a better predicament than the ordinary balloon, for the wind may be of a strength and direction quite unknown to the navigator.

A dirigible balloon is a lighter-than-air machine moving entirely in air. Very different is its situation from that of an Atlantic liner. Certainly the liner is a lighter-than-*sea* machine, but only a portion of the liner is in the sea, a great part of it being above the sea in comparatively intangible air. Those who dream of the immediate possibility of aerial liners at all comparable to ocean liners in regard to power over the elements are forgetful of this consideration. It is certain that airships will often go out of their course above the clouds and in changing winds.

Aerial navigation is entirely different from sea navigation for the reason that the craft is totally immersed in the element in which it moves. Its case is, however, similar to that of the submarine, save that the submarine has only to reckon on currents and tides of, at most, five or six knots per hour, whereas aircraft commonly fly in air currents of twenty and thirty miles an hour, and not infrequently in currents up to fifty miles per hour. Further, whereas sea currents are mostly charted and regular, air currents are extremely irregular, are little understood, and are apt to spring up with little warning in great strength from any direction. Probably many aerial currents are as constant in their general position as are sea currents, but varying in power.

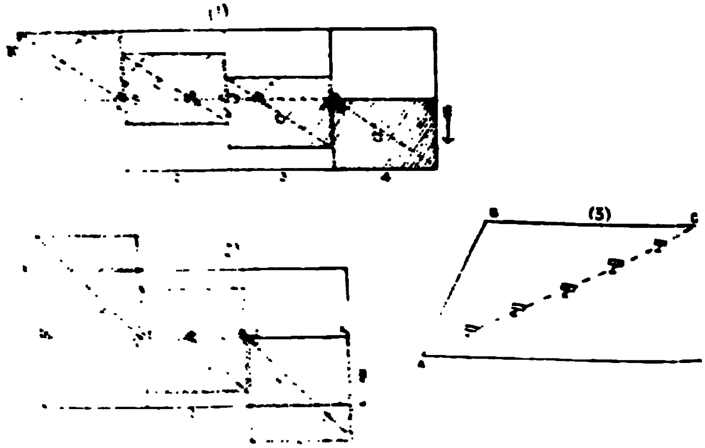

FIG. [illegible]. EFFECT OF WIND ON DIRECTION OF FLIGHT

No. 1. A is the starting point and B is the destination. The shaded [illegible] the wind moving in the direction of the arrow. The [illegible] line [illegible] is the path of the aeroplane with regard to [illegible]. The [illegible] line is its path with respect to the earth.

No. 2 shows the effect of a stronger wind than No. 1, i.e. a longer body of air moves in a given time. The aeroplane therefore has farther to travel [illegible] and takes longer to arrive at B.

No. 3. [illegible] miles per hour sets course for B without allowing [illegible] at [illegible] miles per hour from left to right. It [illegible] from B to C. In two hours, therefore [illegible] of arriving at B finds itself at C.

As Colonel Renard wrote long ago: "For the aeronaut, who belongs not to the earth but to the atmosphere, wind does not exist." Wind must be regarded as a body of air in motion carrying the aircraft along with it. The machine can move about that body of air, and its motion, relatively to the earth below, is the component of its own movement with the movement of the body of air. Again, as Colonel Renard says of the airship, and it applies equally to the aeroplane, "The wind changes nothing, either in the nature of the efforts it has to undergo during the voyage or in the speed of its displacement in relation to the aerial ocean in which it floats; and everything goes on as if, the air being perfectly motionless, the earth were flying beneath it with a speed equal and contrary to that of the wind."

Yet it is sometimes said that an aircraft can "tack" to and fro like a marine vessel, to gain a point in an adverse wind!

It is usually correct to say that the rush of air is always in the face, and that its strength is that of the independent speed of the machine. There are moments, however, when the rush of air varies in strength and direction due to sudden irregularities and gusts, and at times through the machine slipping away to one side when turning. In the case of gusts, the machine does not immediately respond to the difference in the speed of the wind, and for a moment its independent speed in the air is less or more, as the case may be, than in normal flight.

A good deal of misconception is based upon this matter. Some pilots maintain that an aviator feels greater wind pressure when he is flying against the wind than when he is flying with the wind. This does not agree with accepted theory, since every machine to get the proper amount of support must pass through the air at a certain speed. But there exists the difficulty, on the other hand, further explained in another chapter, of keeping the head of the machine down when flying against a gusty wind, or of keeping the head up and the altitude maintained when flying with the wind. Very many pilots and people who have been up as passengers have failed to notice the slight difference, yet it seems perfectly reasonable to suppose that against the wind an aeroplane may be to an extremely small extent self-supporting due to the pulsation of the wind. It is well known that birds, in many cases, avail themselves of a head-wind when soaring. In this connection the author ventures again to mention the theory he put forward some years ago to the effect that the onset of a gust, or of each smallest pulsation of wind, is more sudden than the falling off of the wind's velocity at the end of a gust. If this is so it might considerably affect the behaviour of a flying machine, or a bird. According to universal experience gusts "die away." The ordinary anemometer could scarcely be expected to show this peculiarity, especially in the small pulsations of the wind.

With differing temperature and with varying humidity the buoyancy of the air varies, and the weight and behaviour of the aerial craft will after. In different conditions of the atmosphere, moreover, engines behave differently.

The difficulties of fog have already been referred to, but the commonest danger besetting aircraft is that of violent winds. When an ordinary gale of wind is blowing at the rate of forty or fifty miles an hour on the ground there is often a hurricane of sixty, eighty, or a hundred miles per hour in the upper air. In such winds aircraft must drift great distances; and any attempt to land an airship would almost certainly end in disaster. It seems a far cry to the day when harbours for airships will be so common that aeronauts can take the chance of storms with impunity, and for many a year the danger will have the effect of limiting the number of days in the year when airships can venture aloft. Some ready method of bringing an airship to anchor within harbour will have to be devised, so that the services of many scores of men will not be needed. The method will probably take the form of an apparatus to secure the airship, and then to move it slowly into its shed. These sheds will have to be huge constructions, say, 600 feet in length and 80 feet in height, or harbours might be excavated. Again, shelter walls capable of being turned on a pivot might be devised. In foggy weather captive balloons may be sent up equipped with powerful electric lamps, with wireless telegraphy apparatus, and with various other signalling appliances. One function of these captive balloons would be that of serving as "lighthouses."

Every aeronaut knows how difficult it sometimes is to recognize even familiar country from above, and that very great care is necessary to avoid going astray in one's calculations over unknown localities. Seen from above, hills and towers which serve as landmarks on the ground are scarcely visible. From an altitude of 5000 feet a hill of 1000 feet, if its contour be gentle, is easily missed.

With the aid of the compass it is easy to ascertain the *direction* of flight, but unless landmarks are recognized it is impossible to judge the *speed*.

With a map on a scale of ½ inch to the mile, showing the lines of the roads and the shapes of the villages, it is often easy enough to ascertain the locality even over unknown country; but the aeronaut travels swiftly, and a full equipment of ½ inch scale maps would be a serious item in the weight of his load. Moreover, he is often above clouds for a considerable period, and then when he views the earth again it is very difficult, and frequently impossible, to pick up the locality by a study of the map.

"Relief" maps are of little use to the aeronaut, and there is need for the construction of large distinctive marks by day and lights by night, at distances of about ten miles or so apart, indicating by number or shape the localities. These marks would, of course, correspond with marks on the balloonist's chart. They could be made to vary in colour as well as in shape, and each county might have its own special method.

In suggesting some series of marks, it is obvious that simplicity must be the main consideration. In the United Kingdom the system of motor-car registration marks may supply a basis for special landmarks for aeronauts. These marks vary with the different counties, and with various divisions of the larger counties. They consist of a letter, in some cases of two letters. These letters could be formed with lumps of chalk on the ground throughout each district at intervals of not more than ten miles, so that the aeronaut catching a fleeting glimpse of earth would be able to see one. The letters should be of plain shape, and should be fully 50 feet in length. At night they could be marked out in rows of lights. And since aeronauts frequently pass from country to country, some scheme of distinctive national marks, in addition to special local marks, would be necessary. These matters will have to be arranged at some international convention on aeronautics. In 1913 the provision of landmarks had been begun in France, and when the Great War began several scores of these landmarks had been made.

As to special aeronautical maps, a ½ inch scale map is useful, but it is, for the reasons already given, very far from perfect. The map that would be of use to aeronauts when travelling long distances would be a natural feature colour map, of a scale of, say, three miles to an inch, showing the general appearance of the country as seen from above; that is, with all its excrescences and protuberances flattened, and with differences of colour the only variation—the white lines of the roads, dark green of the fields, darker green of woods, brown sand or ploughed land, black lines of railways, villages and towns marked and distinguished by their shape, and the predominant colour of the roofs, grey here, red there. All the colours are mellowed by distance seen from a height, and, of course, they vary slightly at different seasons of the year. They vary then in hue, however, but very little. The woods turn a lighter shade in summer; the corn-lands are green for a few weeks, but the yellow of harvest is succeeded by the darker hue of the brown of the stubble and the ploughed land.

Combined with that of marks to guide the aerial traveller in locality and direction is the question of conveying useful information to him. It will often be of great importance to him to know the strength and exact direction of the wind. It may not be possible for him to ascertain these with absolute accuracy, while he is in flight, by his own observations. Lighthouses have been suggested throwing a long beam in the direction in which the wind is blowing. For aircraft provided with wireless telegraphy matters are much simplified.

These considerations must be borne in mind in conjunction with those concerning the machine—the capabilities of aircraft, the instruments they carry, the amount of skill and endurance they demand from their pilots, and so on.

An aeroplane is a vehicle that derives the necessary lift and speed from one or more air-propellers driven by one or more motors. It depends upon speed through the air for its ability to remain in the air, and for each machine there is a minimum speed below which horizontal flight cannot be maintained.

The vertical steering of a flying machine is obtained with a horizontal plane, called the "elevator," in the front or the rear, or both, to be elevated or depressed at will. A very small movement suffices to produce a great effect on the upward or downward direction of the machine. For steering to right or left a vertical plane or planes at the rear is a common device.

For its safe and sure control and navigation an aeroplane must carry a compass, an air-speed indicator, or an inclinometer, an altimeter, an engine-speed indicator, and a side-slip indicator. The air-speed indicator shows the speed through the air, and informs the pilot of circumstances which his physical sensations would be unable to detect. For example, speaking quite broadly, in a cloud or when flying at night, while the engine continues to run healthily, if it is observed that the air-speed indicator shows a decline of flying speed below a certain safe minimum it is known that the machine has got into a tail-down position and is in danger of becoming "stalled," a prelude to a fall either sideways or backwards. Again, if with unaltered engine-speed the air-speed increases beyond a certain point it is known that the machine is heading on a downward slant. Needless to say, the reading of this instrument should be taken in conjunction with the engine-speed indicator.

An inclinometer affords similar information, but not so accurately. Although the inclinometer has been largely superseded it will be well to mention its characteristics. The majority of designers of inclinometers have failed to produce the ideal instrument, for the simple reason that they, as well as practical flyers, have failed to perceive one of the factors that should be taken into consideration. Most inclinometers have been based upon the spirit-level principle, a fluid ascending or descending a scale, and showing the angle of the machine to the normal flight angle, and thereby indicating to the pilot the approach to dangerous tilting up or down. The principle, of course, fails in one respect: it does not enable an instrument to be made that will show the machine's angle relatively to the direction of the air-flow. The pilot might be quite unconscious of the fact that an upward- or downward-trending current may be blowing, but obviously if one of these conditions prevails it must affect the range of angles within which safe flying is possible.

An "incidence indicator," however, such as that invented by Orville Wright, consists of a wind-vane sensitive

"Flight

A FIGHT IN THE AIR

French Morane monoplane engages a German "battle plane.'

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to every change in the direction of the flow of air past the planes, and geared to an indicator needle, which shows the angle of the machine in relation to the flow of air. The instrument is undoubtedly in this respect an advance on previous kinds, since it takes into account an essential cause of instability. It is important to remember that what may be a dangerously steep diving position under ordinary circumstances may in the case of flying through a slanting current be perfectly safe.

Now, recognition of this fact leads to a number of very important conclusions. In the first place it points to the great difficulty with which designers of machines with a big range of speed have to contend. Until such aeroplanes are furnished with wings whose angle to line of thrust or area can be varied in relation to changes of engine power, it is unavoidable that on the top speed the machine must be driven with the planes at a very small angle of inclination; and it follows that there is a very small margin of stability, and with little provocation the pressure may be transferred from the lower to the top surface of the planes. No speed-range machine whose top speed is only obtained by flying at a very flat angle can be regarded as a success.

No less important is the effect of the recognition of this cause of instability upon the value of many contrivances for giving automatic stability, and especially contrivances which depend upon the force of gravity, or upon any pendulum arrangement. Apart from the inherent faults of the pendulum automatic stabilizer, which appear to be impossible to overcome completely, there exists the grave defect that a machine's safety does not in normal flight depend altogether upon its maintaining a level in respect to the centre of gravity, but to some extent upon its position relatively to the flow of air—in other words, the movements of the centre of pressure are the important factor.

As to the compass used by the aviator, it must have a slow-moving needle floating in some thick liquid; it must be carried in a vibration-proof bed, and it must be adjusted against deviation caused by metal in the machine.

The first aeroplanes were cumbersome machines on the ground, and required outside assistance to start, an operation that involved giving a violent turn to the propeller which, in the case of engines of the rotary type, called for a great exertion of physical force. Numerous accidents have arisen from the necessity for the operation. Means for the self-starting of aeroplanes were gradually adopted, and efficient military aircraft, as early as 1913, were as independent of outside aid as a motor-car.

Until 1914 speed lay with the monoplane, some types of which flew in the Gordon-Bennett of 1913 at over 100 miles per hour. These craft were, however, mere racers of no practical utility, and already they were being superseded by British biplane designs, small "scouts," in which head-resistance was cut down by constructional refinement, and flight at comparatively low as well as high speed was possible. Several types were capable of flying at from about forty to ninety miles per hour, and the range at both ends of the scale gradually extended.

The flight of all aeroplanes is dependent upon the maintenance of a certain speed, and since the speed depends upon the motor, failure of the motor compels a landing. The result was that even when the duration of flight increased, as it did in 1914, to twenty-four hours, it was unsafe to fly an aeroplane in foggy weather or at night, the latter at any rate except in visible vicinity to a well-lit aerodrome; and even then landing called for uncommon skill.

For this reason dual-engine machines were designed, at first with very little success owing to the difficulty of coupling the engines. And at the best the dual-engine aeroplane was but little better than the single-engine craft unless it could maintain flight with only one of its engines at work.

The Russian designer Sikorsky anticipated these problems and produced an aeroplane driven by five engines as long ago as 1913. Curtiss, in America, was at the same time designing a triple-engine aeroplane for crossing the Atlantic. The exigencies of the Great War spurred on invention in this direction, and by 1915 a number of independent designers were producing multiple-engine machines.

Among the practical considerations of aviation are the amount of fuel required for a given period, and the probable distance that can be covered in that time. The storage of the fuel so that, as it is consumed, the balance of the machine is not endangered is an obvious matter for care, as is also the disposal of engine, pilot, passenger, and all the other items in the load.

Taken almost at random, and given here merely with a view to indicating the nature of the data that influence design, are a few facts relating to petrol and oil consumption. The "Albatros" aeroplane that achieved a flight of twenty-four hours twelve minutes in 1914 was driven by a 75 h.p. Mércèdes motor, and used up 600 litres of petrol and 50 litres of oil, a total weight of about 1070 lbs., or 45 lbs. per hour. A Green engine, of that period, of 65 h.p. used 4 gallons of petrol per hour—30 lbs.—or, with oil, about 32 lbs. per hour. An Austro-Daimler of 120 h.p. used 9 gallons per hour=67 lbs., or about 72 lbs. per hour including oil. The Gnome 100 h.p. used 8½ gallons per hour, or 64 lbs. and about 6 lbs. of oil, making about 70 lbs. per hour altogether. On account of their extravagance in lubricating oil, rotary engines, speaking generally, are less economical of load in flights of six hours and upwards than are motors with fixed cylinders.

Seaplanes offer a difficult problem. To designers t
present the difficulty of the floating carriage, the
being to make a seaplane that will be a real sea-go
craft, and that will at the same time fly efficiently.
flyers the seaplane is not less difficult to alight with t
is the overland machine. The idea that water, be
liquid, makes the shock less dangerous must be
missed. If the seaplane strike small waves at a speed
sixty miles per hour it is something like driving a mot
car at the same speed over a heavily ploughed field fro
hard. In fact, the seaplane requires an even stou
under-carriage than the ordinary aeroplane. And furt
when the sea is calm the pilot often finds it anything
easy to see when to flatten out to " land," the appe
ance of the surface of the water being very deceptive
to height.

For these and other reasons—until 1916—in comp
son with the overland flying machine, the seaplane
but little developed, and although Great Britain
made more progress than any other country the c
built were not really seaworthy. It was the object
designers to produce a craft that would float in c
water for an indefinite period without suffering dama
This quality, combined with airworthiness, is an essen
feature of the seaplane, but no machine resting on flo
had at that period endured the floating test for m
than twenty-four hours without becoming waterlogg
This was one of the reasons for the attention given
the development of machines consisting of a boat
mounted by planes, which type, however, had cert
disadvantages. With the use of larger and more hea
engined craft, designers had greater scope for the solut
of all difficulties, and here steady progress was made,
it was the confident belief of many designers that
really seaworthy aeroplane would be produced.

CHAPTER VIII

PRINCIPLES OF MECHANICAL FLIGHT

(*a*) *Kites and Soaring Birds*

THE general underlying principles of flight are not difficult to understand, and can be explained without the aid of mathematical formulæ. In attempting to present the subject in this way, general terms and figures must suffice, so that the information thus presented would not be exact enough for the aeroplane designer. The author is, however, convinced that the time has come when in a book of this description the amount of scientific and technical information that can be given is much greater than in "popular" treatises on aeronautics hitherto published.

Birds fly, as the Duke of Argyll said, not because they are lighter than air, but because they are immensely heavier. "If they were lighter than air they might float, but they could not fly."

When man first aspired to fly, he naturally looked for his earliest lessons to the birds, the creatures who already possessed the gift. Flapping wings were the most obvious means, and the fact that many birds perform long flights without flapping their wings did not at first influence man's attempt at aerial navigation. At a very early epoch men sought to copy birds by making for themselves flapping wings.

The methods of natural flight are various. The flight of birds can be divided into three broad sections:

1. Flight by flapping wings.

2. Flight by gliding, with impetus gained during wing-flapping or from gravity.

3. Soaring—flight without moving a wing, achieved against the wind. The albatross and buzzard can pursue soaring flight for hours at a stretch.

There are many features of natural flight which continue to be the subjects of controversy. Thus, soaring flight is a most complicated subject, and is not fully explained. Through some force not yet accurately determined—possibly through variations in the velocity of the wind—a bird can maintain itself and move forward in the air for long periods and can even rise without flapping its wings (see page 108).

On the subject of the mysteries of bird flight, J. Lancaster writes in the *Engineer :*

"Some species, such as the condor and frigate-bird, may be said to live in the air. The latter will not touch a rigid support for a month, stealing their food from fish-hawks, and floating in great circles to the height of a mile or more while it is digested. The condor carries its 20 lbs., with an additional 10 lbs. of freshly-gorged carrion, to an altitude of three miles, and serenely waits for an empty stomach to return to earth. The great whooping crane stretches its wings at Winnipeg, and at the elevation of a mile migrates to some lone island on the shores of the Gulf of Mexico, and a field-glass and close and long attention will detect no motion in its straight-line flight, or in the endless circles of the frigate-bird and condor.

"Is there something wrong? Is there a mistake somewhere? If a 30-lb. condor can circle round for six days high in the air, why cannot a man? If the great buzzards anywhere about the shores of the Caribbean Sea can be seen 300 days in the year floating in the sea-breeze over beaches, on the look-out for dead fish, without a wing-motion, for hours, why cannot a man float in that same wind? He can encase himself in surfaces as large—why must his attempts end in failure? A frigate-bird can move upwards for half a mile at a velocity of 100 feet per second, with no visible wing-motion whatever."

Dr. E. H. Hankin, whose extensive and valuable observations of the soaring flight of birds in India form one of the most important contributions to the literature of bird flight, has put forward a most remarkable theory. He came to the conclusion that certain conditions of the atmosphere, and the quantity of sunlight, had a great deal to do with the "soarability" of the air, for he observed that birds could soar in regions where there was no evidence of any upward current to assist them. He assumed that air, under the influence of sunlight, contains a store of energy, which he named "ergaer," that, in some manner yet to be explained, is set free by the outstretched wings of certain birds.

FIG. 20. A BIRD'S SOARING FLIGHT

It is important to observe the enormous range of wing-length between the short-wing birds of the quail and pheasant types, and the long-winged hawks and sea-gulls. Beyond the bird-scale there are insects, such as the butterfly, with a very great proportion of wing-surface to body. But the smaller the creature, the more rapidly does he use his wings (see Marey's table on page 310).

Between the small creatures and the large there are many different kinds of flapping-wing flight. Small birds, like the sparrow, are able to begin flight from the ground. Some larger birds have to run along the ground before they can mount into the air. Soaring birds, such as the albatross, practically live upon the wing, and for a great part of the time exert no muscular power in keeping aloft. Some birds are only occasional flyers, but when they are on the wing they exert great power, and fly very rapidly, generally in a straight line. In this class are included partridges, pheasants, and geese, all of which have comparatively small wings, which have to support much more weight, relatively to their size, than do the wings of the soaring birds.

How great is the difference between the work performed by the various types of wings may be seen from the fact that the swallow's wings support only 0·276 lb. per square foot of wing-surface. At the other end of the scale are the duck's wings, the same area of which has to support 2·280 lbs.

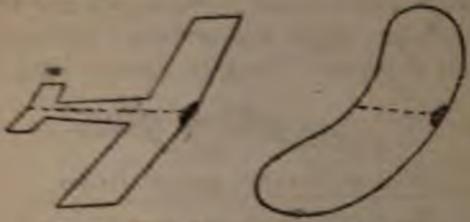


FIG. 21. TWO SIMPLE PAPER GLIDERS
Can be weighted with sealing-wax or split shot.

It appears to be impossible for man to imitate by any mechanical device the bird's flapping wings, although attempts have been made to do so. And it appears to be equally impossible to imitate soaring flight for, to be successful in this direction, it would seem that man would have to acquire the bird's marvellous instinct in taking advantage of different and varying conditions of the air.

In some aeroplanes the wings closely resemble in shape the wings of birds, and it is easy to make a paper toy with parts roughly proportionate in weight to those of birds, and such an appliance will glide gracefully across a room if given a slight impulse; or, like a well-designed aeroplane, it will, from a fall, pick up its own gliding path.

From the example of the gliding and soaring bird it ppears to be a direct step to the kite, which played a rge part in the early development of the aeroplane. he simpler kites are, in fact, aeroplanes held by a cord t an angle to the wind ; and all kites, no matter how omplicated in form, are based on this principle.

When the string breaks the kite falls to the ground, eking always to present its edge to the resisting medium. s long as the string holds the surface at an angle to the ind, it is buoyed aloft. Relatively to the movement of

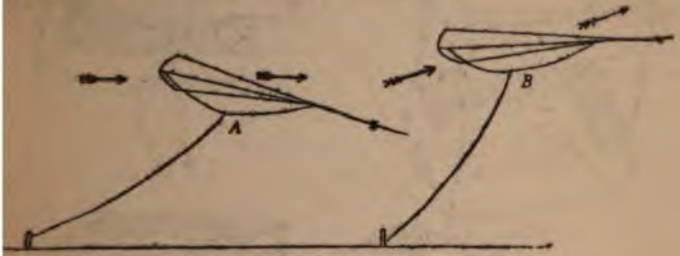


FIG. 22. PRINCIPLE OF THE KITE

The arrows show the direction of the wind. In A the wind is horizontal. In B the wind has an upward direction, and the kite, keeping the same angle as before to the pressure of air, comes to a position more nearly over the head of the kite flyer.

e air, as the diagram shows, the kite is always falling. he air constantly rushes past it. If the wind drops, the ite comes to the ground. In an upward current of air kite will take up a position almost directly over the ead of the operator, although its angle remains about e same in relation to the direction of the wind.

The kite is an apparatus which, despite the fact that is heavier than air, will remain aloft, carrying with it ot only its own weight, but, in addition, the string or ire with which it is held. And if the kite be large enough will lift not only a rope or wire, but a man also.

The kite is kept to the wind by the control of the operator low. The task the early aviators set themselves to accomplish was to combine direction-control and power in a kite.

It was first necessary to discover the best form of kite, but it was not really until 1894 that men began seriously to tackle this question. Eleven years previously Douglas Archibald experimented with the object of finding out a suitable form of kite for conducting meteorological experiments. The next systematic work was in the United States: on August 4, 1894, for the first time, automatic recording apparatus was sent up on kites from Blue Hill. In 1895 Professor Marvin, in Washington, made his important studies on kites, and during the summer of 1898 he arranged seventeen kite stations the United States Weather Bureau. In the same the raising of men by means of kites was achie

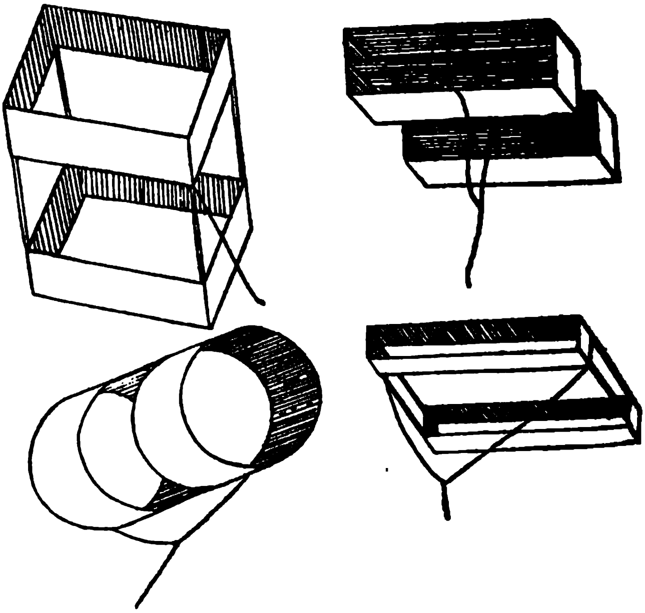


Fig. 23. Various Forms of the Hargrave Kite

Major Baden-Powell, by Lieutenant Wise in America, and by the Military Balloon Corps in Russia; and at the Russian Naturalist Meeting that autumn various persons were lifted up, though not to any great height. S. F. Cody raised men to a height of over 3000 feet with the kite that was adopted by the British War Office.

The various forms of kites have given widely different results. The ordinary kite, the familiar toy of childhood, has but little stability, and too small an angle of ascent. A better form is the Malay, known to children as the "finbat," having, in addition to the one-plane surface, a smaller plane projecting at right angles from the middle.

The Hargrave "box kite" consists of two or more cells, whose various surfaces resist the air at different angles, the result being considerable stability. The illustrations show some of the forms used. Hargrave employed two rods, which served to connect the cells, while the other longitudinal rods extended only the length of a cell; these formed the corners, and were held in position by diagonal ties, which stretched from them to the longer longitudinal rods. A kite with a large number of cells is more steady in gusty weather than a kite with only one cell, the reason being that the force of the gusts is diffused over various parts of the sustaining surface instead of concentrating at one place. Well-built Hargrave kites weigh about 1½ lbs. per 10 square feet of "lifting surface," and require (at a height of 100 feet) a wind velocity of about twelve miles per hour. The principal "lifting surface" is the cell fronting the wind; the other cell serves partly to correct any pitching tendency. The early cellular type of aeroplane was an application of the principle of the Hargrave box kite.

If the lifting surface of the Hargrave kite is slightly arched it will rise more steeply—at from 60 degrees to 67 degrees, instead of from 55 degrees to 60 degrees. In practice it proves best to have a curve whose highest point lies far forward, and whose front portion is formed of some stiff material.

There are many other kites. One that requires even less wind than the Hargrave, than which, however, it is less stable, is the Slat. This type requires only 80 per cent of the wind velocity necessary for the Hargrave, namely, ten miles per hour as against twelve miles per hour (at a height of 100 feet).

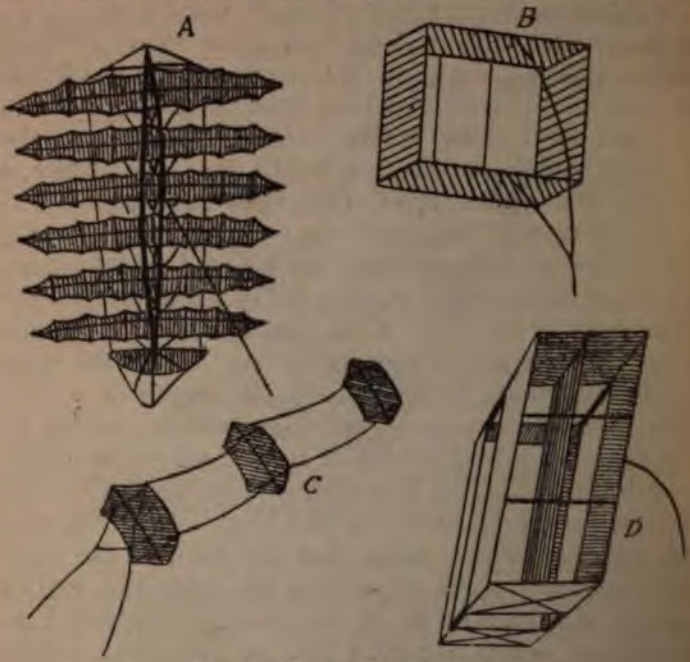


FIG. 24. SOME TYPICAL KITES
A. The Nikel Kite. B. The Slat Kite. C. A team of Baden-Powell Kites. D. The Marvin Kite.

A superficial area of 180 to 250 square feet is the greatest a single kite can conveniently possess. If more is required, extra kites must be fastened to the same cable. These give increased lifting power; and, further, eam pulls more regularly than a single kite: they ct upon one another in the changing velocity and ction of the wind. Twelve feet square—144 square :—is calculated to have a lifting power of about lbs. in a steady breeze. A plane area of 180 square t is necessary to lift an average man.

novel type of cellular kite was that introduced by ham Bell. This was the tetrahedral cell kite, each , as the name denotes, being a triangular pyramid.

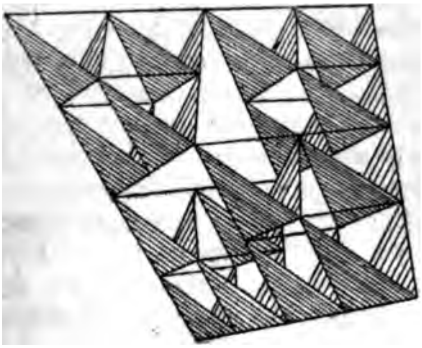


FIG. 25. GRAHAM BELL'S TETRAHEDRAL CELL SYSTEM
As applied to his kite and his aeroplane.

o sides of each cell consisted of fabric, the other was n. The two closed sides, with their points extending vards, were not unlike a bird's outstretched wings. l made extremely successful kites consisting of a large nber of these cells placed together. In one apparatus r 3000 cells, arranged in the form of a huge blunt lge, possessed great steadiness in the air. In a sudden t the only effect produced was a slight shivering. The entor claimed that a flying machine built on these s would possess a degree of stability unattainable by other form.

motor, air-propeller, and rudder would turn the kite a flying machine: the aeroplane is a self-propelled kite. The pull of the kite-string is, in the aeroplane, replaced by the thrust of the revolving screw.

(*b*) *Resistance of the Air*

The air is a fluid, light and comparatively attenuated, yet of a definite weight and substance. It is the element that man breathes, and it seems without density or form or colour. But it is heavier than many gases, which, nevertheless, are ponderable. It is twice as heavy as coal gas, and about fifteen times as heavy as hydrogen. It is so substantial that when moving at a great velocity it has been known to hurl locomotives off the track; and its movement constantly agitates the ocean, whose water is nearly a thousand times heavier than the air. In high wind its pressure on a building amounts to as much as 1 cwt. per square yard. And since it can, when in motion, produce such effects as these, it follows that when still it will offer great resistance to objects borne rapidly through it. The larger the surface of these objects, the greater is the air's resistance. It is easy to drag a plate through the water edgewise, but to force a plate through water flat requires considerable strength.

The parachute is a common and convincing way of demonstrating that the air is a very tangible substance, offering great resistance to bodies of a certain form. The time occupied in falling with a parachute may seem long to readers who have not given attention to the subject. A fall from a height of 10,000 feet occupied thirty-five minutes. Frau Poitevin took forty-three minutes to descend 5500 feet in a parachute. A parachute about 35 feet in diameter flat, or about 28 feet in diameter arched, will give so much support to a man that w its aid he can fall from a great height without aligh so heavily as to be hurt.

Air, being an elastic compressible fluid, differs greatly om water, which is incompressible. The density of e free air at any point is determined by the weight has to support : and this diminishes with altitude. magine a high stack of blankets ; the top blanket is ft and thick, the bottom is crushed hard and thin by e weight it bears.

On this basis the barometer indicates the density of e air, or the atmospheric pressure, a simple form of arometer being a U-shaped tube of mercury, the liquid etal weighing in a tube of 1 square inch section about lbs. per 30 inches. A column of the atmosphere of the me section weighs about the same. One end of the rometer tube is open, and the atmosphere bearing on is open end pushes the mercury down, more or less, cording to its weight. As the mercury goes down one de it rises in the other, where the tube is graded, sually in inches, and a " high " or a " low " barometer indicated.

This varies from day to day slightly, according to the ondition of the weather, and it varies a great deal if the arometer is taken up a mountain, or in a balloon, when e weight of the atmosphere on the open end of the tube becoming less and less, the mercury rises there nd falls on the graded side.

The barometer is marked up to 30 inches. The atmophere extends to a height of more than forty miles. ssuming a reading of 30 inches at sea-level, the barometer ill fall to about 29 inches at a height of 1000 feet. It ill fall nearly another inch at the second 1000 feet, and on, at a diminishing rate, so that at 20,000 feet the arometer gives a reading of about 14½ inches.

The aneroid and the altimeter are instruments based n this principle, and they indicate altitude by noting tmospheric density. The density of the air decreases in roportions of 0·13 per cent per mm. of mercury, or

3·25 per cent (about $\frac{1}{30}$) per inch of mercury. It will b noted that $\frac{1}{30}$th, or any other proportion, becomes les and less as the total decreases. In other words, wit ascent every inch of mercury represents a larger colum of air than the previous one. Thus, at a height of 30,00 feet an inch of mercury represents about 1600 feet.

Weather affects the barometer, as it does also th altimeter and the aneroid. It is, therefore, necessary fo the aeronaut to examine the instrument before he make an ascent, and either note its reading and allow for an variation, or else set the hand to zero.

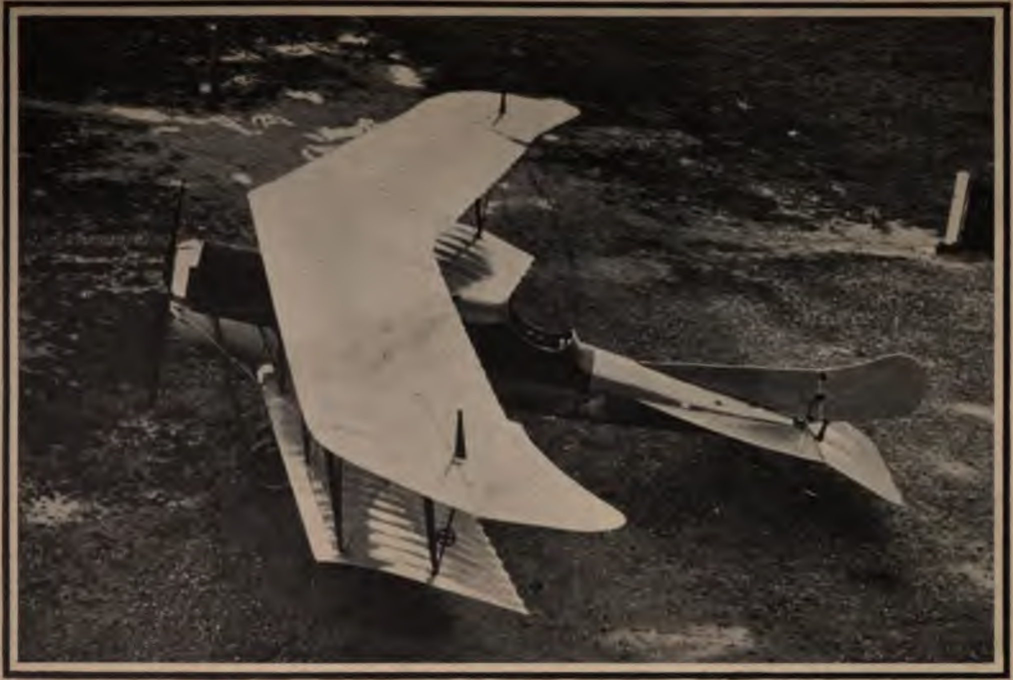
Temperature affects the density of the air by abou $\frac{1}{500}$th part of its volume per degree Fahrenheit. A rise o fall of 20 degrees therefore affects the density or th weight of the air by $\frac{20}{500}=\frac{1}{25}$.

Humidity makes air lighter, since water vapou weighs 0·623 of air, and air laden with water vapour is therefore, affected as regards weight in much the sam way as if it were mixed with coal-gas or hydrogen ; bu the effect is very slight.

It will be well to summarize briefly the principal law relating to the flow of air over planes and bodies o various shapes.

On rigid surfaces the pressure of the air varies a the square of the velocity, by which may be mean either the motion of the wind against the surface or th motion of the surface through the air. This law hold good up to velocities of 200 m.p.h. or so. The pressur varies directly with the area of the surface. The speed an area being known they are multiplied by a coefficient, whic varies according to the shape of the surface. For man shapes the coefficient has been ascertained by experiment

In mechanical flight the resistance of the air is the mean of support. Support is derived from resistance, whic at the same time hinders speed. Aeroplane builders ar ever seeking by refinement of design to diminish head



News Illustrations Co.

A GERMAN SELF-RIGHTING AEROPLANE

The D.F.W. Biplane.

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resistance and thereby obtain greater speed and, as one consequence, improved lift-drag ratio. As already said, to obtain support from the flow of air it does not matter whether the air is moving, or whether the plane is travelling; and both causes may be operating together. The motion of the body in relation to the air, and not to the earth, is the important factor. From the remarks already made on the properties of air it will be seen that the greatest support is obtained from air that is cold and, thereby, dense, and also that is under the greatest atmospheric pressure.

The resistance of a square plate facing the wind varies, as we have seen, according to the square of the velocity, and directly as the size of the plate. The coefficient (K) in this case is 0·075, if calculating by kilogramme metres, or ·00142, if in lbs. per square foot. Thus, 1 square m. at 1 metre p.s. gives a resistance of ·075 kilogramme = 75 grammes. At 2 metres per second this would be 4×75, or 300 grammes. This assumes air under a barometric pressure of 30 inches and a temperature of O degrees centigrade.

In falling speed would continually increase, but as air-resistance increases as the square of the speed the moment comes when acceleration of speed is balanced by resistance. After that moment the body falls at a uniform rate, or rather, it would fall at a uniform rate in air of uniform density. In the case of falling bodies the law of gravity determines the rate of fall, materials of great specific gravity, such as lead, falling faster than those of low specific gravity, such as feathers.

A bullet attains great velocity before the resistance of the air prevents further acceleration. But a parachute with a man hanging to it ceases to increase its rate of descent almost directly it opens, on account of the great resistance to the air offered by its shape. A ball of copper dropped from a height of 16 feet will reach the ground in one second. If the ball be beaten out to a thin sheet it will take a long time to fall.

In mechanical flight the resistance of the air is used to obtain lift. For this purpose a plane-form is selected giving the best results. And it is important to know how to measure the air-resistance encountered by various plane-forms driven at the speeds necessary to keep them aloft.

The resistance of a simple plane-form, like a sheet of stiff cardboard, varies almost exactly as the sine of the angle at which it is held to the air. But each shape, as already said, has a different coefficient only ascertained by experiment. It will be understood, therefore, that the designing of aeroplanes, which are complicated structures having wing surfaces of infinitely various curvatures and angles, besides various parts which do not afford any lift, involves elaborate calculations.

(c) *Planes*

With simple plane surfaces similar to the extended wings of the bird or the planes of a kite a man can carry out limited flights, by gliding downwards through the air from elevations, without expending muscular energy. Chanute made 700 glides on one apparatus of this description. From the laborious investigations of the early aviators and experimenters in this direction is derived the basis of knowledge of the principle of aeroplanes. The supporting power depends on the shape and size of the surface used, and the speed at which it is driven. From the work of the early experimenters certain data are obtainable, and certain formulæ have been established.

In considering these the student is first confronted with a fundamental difference between the motion of aeroplanes in air and that of ships on water. Ships are propelled through the water in the line of least resistance. Their direction is in line with their greatest length. The direction of the aeroplane is at right angles with the line of its greatest length. We observe the same principle in bird-flight, which is with wide-extended wings. The ship resembles the fish that lives in the same element. The aeroplane is like the bird.

There are exceptions to these general rules, however, which it will be well to glance at in order to appreciate the main principle more thoroughly. The paper dart made by children has occurred to some as a possible prototype of a flying machine. It is, indeed, admirably formed for piercing the air; but a fatal objection to its shape is that it has but little lifting-power, for lift depends in a large degree upon the proportion of the front edge to the total area of the plane, a matter to which further reference will be made in the proper place.

Another exception is the dirigible balloon, in which case it is necessary to present as small a surface as possible to the air. A moment's reflection, however, will show that between the dirigible balloon and the aeroplane there is a broad distinction. The dirigible balloon has lifting-power derived from the gas that inflates it: there is no reason for it to have an extensive "entering edge." To drive its great bulk through the air considerable engine-power is required—so much, indeed, that the form of least resistance must be chosen.

Nature has shown what should be the general shape of the contrivance necessary for mechanical flight. The examples are the various forms of flight with wide-extended wings, not driven point forwards, but proceeding at right angles to the line of their greatest breadth.

The question of the proportion of the entering edge to the size of the aeroplane is one of the most important points to consider. A plane 10 feet square will not lift so much as a plane 100 feet in span and 1 foot in width, although both have the same superficial area. (The word "span" in this connection means the dimension of a plane from right to left. The word "width" means the dimension from back to front.) One reason for the difference in the lifting-power of the two forms mentioned is probably that some small portion of the air slips off at the sides, which are, of course, much longer in the square than in the narrow plane. The longer the sides, the greater the proportion of the unutilized air. The object of the aeroplane designer is to utilize to the full the area of the plane, and so he makes it as long as possible. To check the spilling of air over the sides of his kite planes, Hargrave fitted a small flange, and the use of this flange made a definite improvement, a fact which may seem almost incredible to readers who have not actually experimented with kites.

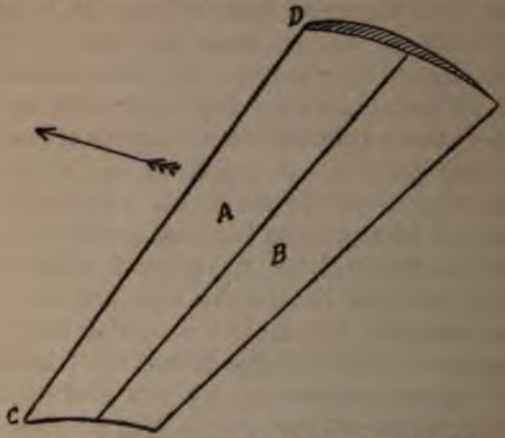

FIG. 26. DISTRIBUTION OF LIFTING POWER

The entering edge is C D. The half of the plane A is equal in superficial area to the half of the plane B, but the lifting power of A is greater than that of B. The arrow shows direction of flight.

It may be assumed that a flat plane 2 feet wide and 100 feet long will lift 2½ lbs. per square foot if driven through the air at a certain velocity and a certain angle. For this lifting-power the speed must, as a matter of fact, be about forty miles per hour, and the inclination of the plane—its upward tilt—1 in 10. Since it is but 2 feet wide, its forward edge would therefore be about 2½ inches higher than the rear edge. Such a plane would obviously be useless for practical flying; it is too long. Therefore, it may be cut in halves, making two lengths of 50 feet each, which may be placed one over the other. A small fraction of the lifting-power is lost, however, by increasing the length of side-edge. But the two superimposed planes, 50 feet in length and 2 feet wide, have a lifting-power under certain conditions of 2½ lbs. per square foot. The planes have a total surface of 200 square feet, therefore the total lifting-power is 500 lbs.

On the other hand, by making it 4 feet wide instead of 2 feet, and 50 feet long, the lifting-power is reduced. The front section retains its efficiency, but the rear section has comparatively small lifting-power.

By increasing the tilt of the rear half of the plane this loss of power is slightly reduced, and by adding a third section at an even greater angle additional lifting-power is obtained. The box-kite with curved surfaces lifts better than one with flat surfaces. The fact remains that the air, having met the plane at its entering edge, can only have its fullest effect near there. It does not bear directly on the plane except near the front edge. No matter how much the angle is increased towards the rear, the lifting-power dwindles; and there is a limit to the reasonable amount of inclination. If the whole of the surface of the plane struck the air simultaneously the effect might be uniform throughout its width, and the lifting-power might increase in fair proportion to increase in size.

There is an obvious reason why flying machines should not consist of a large number of short planes one over the other. In the first place, while by that means a large total "entering edge" would be obtained, the length of slipping edge at the sides would also be increased. Another result would be instability. Here it may be noted that the length of a lark's outspread wings is four times the width. In an albatross the difference is 14 to 1.

The next main points are the shape of the plane and the angle at which it should be placed. Experiments have shown that the best shape is concave on the under and convex on the upper surface, with the thickest part near the front edge—not more than a third of the total width from the front. To counteract as much as possible the dwindling lifting-power of the rear part of the plane it might, as already remarked, be necessary to have that part at a greater angle than the part immediately behind the entering edge; but various other considerations confront the designer.

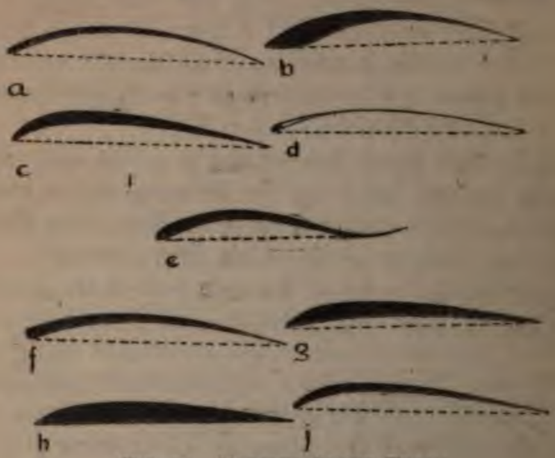

FIG. 27. VARIOUS PLANE FORMS

A. Lilienthal. B. Phillips. C. Blériot XI. D. Farman. E. Concavo-convex. F. Wright. G. H. J. Types tested at the National Physical Laboratory.

The wider the plane the greater should be its curve and tilt; and the greater the tilt, the greater must be the power to propel it, for the obvious reason that there is far more air-resistance or drag to a plane being driven forward at a big than at a small angle of inclination. The reader need only recall the simile of the plate, which is easier to pull through the water edge-wise than flat.

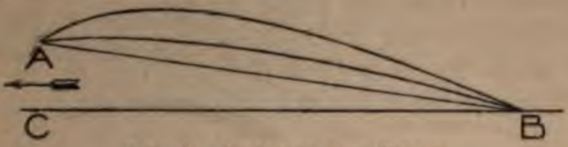

Fig. 28. Analysis of a Plane

A B. Chord. A B C. Angle of inclination. If C B is the path of flight then A B C is also the angle of incidence.

One of the good characteristics of planes with the thickest section near the front edge is that the air passes smoothly over both upper and under surfaces, and leaves the plane at an angle which is a result of the two different angles—that of the upper surface and that of the lower surface. An advantage of this section is that it enables the wing to be constructed hollow, so that strength is combined with lightness. Such a form, on account of the easy flow of air over it, is said to approximate to "streamline" form, which, as Lanchester expresses it, "is one that in its motion through a fluid does not give rise to a surface of discontinuity." The natural streamline form is possessed by most fishes. As the

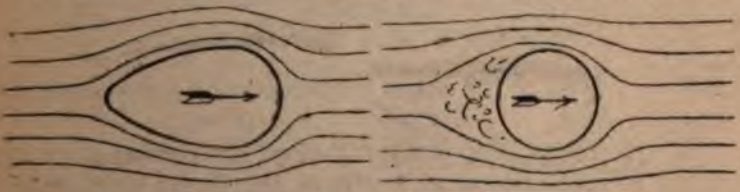

Fig. 29. Stream Lines of Air over Sphere and Egg

Note eddies at rear of sphere. These are avoided by egg-shaped body driven blunt end foremost.

diagram shows, in streamline form the thicker end goes first: experiments have proved that there is more resistance if the thin edge is driven first.

When the inclined plane moves forward there is a pressure of air on the under surface, and over it an area of diminished air pressure or "suck" just behind the top of the curve, materially aiding the lift.

The upper surface is responsible for about two-thirds of the entire lift, from which it follows that the design of the under surface is not the only important factor, but that the shape of the upper surface requires very careful consideration.

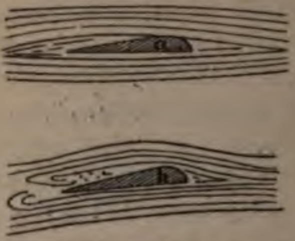

FIG. 30. FLOW OF AIR OVER PLANE
(From photographs in Technical Report of Advisory Committee on Aeronautics.)
Showing on top area of diminished pressure.

In the construction of aircraft of all kinds every part is made to approximate as nearly as possible to streamline form. Airship "hulls" are made after that manner unless some powerful reason exist against it. The later Zeppelins had blunt noses and tapering sterns, but for constructional reasons the rigid type of airship must be very long.

In the case of aeroplanes the struts are usually of streamline section: and where possible groups of members are enclosed in streamline shields.

It is probable that, like resistance, lift increases almost as the square of the speed. As already said, the lifting-power of a plane 100 feet in length by 2 feet in width, at an angle of 1 in 10, and driven at forty miles per hour, is 2½ lbs. per square foot, a total of 500 lbs. The same plane, if placed at an angle of 1 in 20, will lift only 1¼ lbs., unless the speed be increased. But at a speed of sixty miles per hour instead of forty, the same plane will, according to Maxim, lift 2·81 lbs. These calculations are merely given to illustrate a principle; they are not to be taken literally.

The capacity of the aeroplane to sustain a man in the air was demonstrated long before any were fitted with mechanical power. It has already been mentioned that Chanute made 700 glides in his "double-decker" without an accident, and the Brothers Wright worked for years in the same manner before attaching a motor to their machine. The illustrations on pp. 174 and 175 show these aeronauts gliding, the flights being taken from the summits of small eminences.

In the Chanute machine the speed necessary for support was as nearly as possible twenty miles per hour. That is to say, at a lower velocity that particular machine would not leave the ground, the pressure of air not being sufficient to lift the planes. The angle of descent in the Chanute glider was about 1 in 8 or 1 in 10.

The Wright gliders were about 22 feet in length and 6 feet 6 inches in chord. They had no tail, but possessed a hinged horizontal rudder at the front. The angle of descent through the air was about 1 in 10.

The Brothers Wright, as early as 1901, carried the science of aeronautics many steps forward. Wilbur Wright published his conclusions in December, 1901, as follows:—

1. That the lifting-power of a large machine, held stationary in wind at a small distance from the earth, is much less than the Lilienthal table and our own laboratory experiments would lead us to expect. When the machine is moved through the air, as in gliding, the discrepancy seems much less marked.

2. That the ratio of drift to lift in well-shaped surfaces is less at angles of incidence of 5 to 12 degrees than at an angle of 3 degrees.

3. That in arched surfaces the centre of pressure at 90 degrees is near the centre of the surface, but moves slowly forward as the angle becomes less, till a critical angle, varying with the shape and depth of the curve, is reached, after which it moves rapidly towards the rear till the angle of no lift is found.

4. That with similar conditions large surfaces may be controlled with not much greater difficulty than small ones, if the control be effected by manipulation of the surfaces themselves rather than by a movement of the body of the operator.

5. That the head-resistance of the framing can be brought to a point much below that usually estimated as necessary.

6. That tails, both vertical and horizontal, may with safety be eliminated in gliding and other flying experiments.

7. That a horizontal position of the operator's body may be assumed without excessive danger, and thus the head-resistance reduced to about one-fifth that of the upright position.

8. That a pair of superposed or tandem surfaces has less lift in proportion to drift than either surface separately, even after making allowance for the weight and head-resistance of the connection.

These conclusions are recalled as a matter of interest rather than for the sake of the teaching value they possess.

(*d*) *Stability and Design*

The "lift" of an aeroplane is the vertical upward component of the reaction from the pressure of air on the planes. The "drag," or "drift," is the horizontal or retarding force—speaking broadly, the waste due to head-resistance.

Skin-friction is due to the passage of the air on the surfaces. It is quite unimportant in the case of smooth surfaces.

An aeroplane with an unchanging load flying at an unchanging angle flies at an unchanging speed. If the flight be horizontal the lift equals the load. To vary the speed the load or the power must be varied. If the load should decrease, other factors remaining unchanged, the aeroplane will rise; in this case, to remain flying horizontally either the angle must be increased or the power must be reduced.

Mechanical flight would be impossible if there were no means of preserving the balance of the flying machine. Every aeroplane has a certain measure of natural stability, machines in which this quality is strongly marked being known as "inherently stable."

In flowing down the under surface of a slightly inclined plane the air exerts greatest pressure over an area near the leading edge. The position of this area of greatest pressure (known as the Centre of Pressure) changes with the angle of the plane. In the case of a flat plane it is, at O degrees of inclination, right on the edge; thence, with increased tilt, it moves back until, when the plane is upright, it is in the middle of it. With curved planes, however, at all small angles of inclination, the Centre of Pressure moves in the opposite way, and only when the tilt becomes pronounced does the Centre of Pressure begin to recede towards the middle.

Loss of stability is due to the movements of the centre of pressure (or, more correctly, the centre of the area of greatest pressure), which is constantly varying, whilst the centre of gravity remains fixed.

In most aeroplanes the centre of gravity is about midway between the extremes within which the centre of pressure moves to and fro in normal flight. If the centre of gravity be placed below the centre of pressure and the line of thrust oscillations will be set up.

Stability may be automatic, inherent, or controlled. Inherent stability is secured by various methods—laterally, usually by a dihedral setting of the wings, i.e. sloping up to right and left from the body.

Longitudinal instability is the tendency of a plane to lose equilibrium by dipping up and down in the line of flight. In most aeroplanes this is in a great measure overcome by the tail. The "tail" corrects upward and downward instability, and the farther back it is placed the more effect has it; but there is a limit to the distance at which it can be placed from the main planes. If too far back, a "dead centre" is reached; and there is also an obvious constructional difficulty in the way of putting it back beyond a certain distance. There is a tendency to seesaw motion even with a tail, and the aviator must correct this by control of the horizontal rudder or "elevator." Slight reduction of speed causes a flying machine, if ascending, to reduce its angle of ascent; or, if travelling level, to begin to descend. Variations in speed are frequent, and are, to some extent, not within the control of the aeronaut. The tail reduces the effect of these variations; in most machines the aviator must constantly attend to the elevator to maintain even flight.

One reason of an aeroplane's upward cant or "bank" on the outside of the curve (just the opposite tendency to that of road vehicles) when turning in the air is that, in wheeling, the outer edge travels faster and farther than the inner. If, for example, the aeroplane be wheeling to the left, the right edge of the machine travels quicker and farther than the left edge. If the machine be wheeling to the right, it is the left edge that travels faster and a greater distance. As already said, with increased speed the lifting-power is increased. The edge that travels quickest therefore rises above the other.

Among the methods for preserving balance is the flexing wing-tip, first suggested by D'Esterno, and later by Montgomery. The Wright glider was the first machine to which it was successfully applied. In order to reduce the canting up of a machine on the right when wheeling the pilot bends down the rear extremity of the left wing: this increases the angle of that wing and causes the left side of the machine to rise. At the same time the rear extremity of the right wing is elevated by the same control.

The wing-tips are flexed not only to correct loss of balance, but also to make turning movements more quickly and neatly. When an aeroplane turns there is a tendency for the outer edge to rise higher than the inner; but in some machines this tendency is very slight, and, in turning, the speed of the machine causes it to slip away to right or left. Artificial means are used in a great many machines to assist this "banking"; the pilot when turning to right or left bends the wing-tips in order to bring about the degree of "bank" that he desires. The same effect is produced in other machines by means of hinged flaps, or ailerons, at the extremities of the plane.

That longitudinal and lateral equilibrium are closely dependent upon one another will be understood when it is remembered that in canting up to right or left a machine naturally turns in its course, and also dips to some extent. The "tail," by making it easier to preserve a steady flight without upward and downward movements, also makes lateral equilibrium easier to maintain.

Of the different methods of securing stability those consisting of any mechanical accessory have proved least satisfactory. The reader will find a fair account of them in the "Aeronautical Journal," April, 1913, in a paper read by Mr. Mervyn O'Gorman.

What is known as inherent stability—that secured by the form and disposition of the planes—is seen in various examples, of which the chief are the systems followed by Mr. J. W. Dunne, and that embodied in the Etrich and similar types favoured in Germany and Austria and exemplified in the British machines made by Handley Page. A third method is followed in the stability types designed at the Royal Aircraft Factory.

The two former divisions are described by Mr. Dunne in the "Aeronautical Journal," April, 1913, in which the following passages occur. The reader is, however, counselled to read the complete article; it is almost unfair to quote so meagrely from a work of the kind.

"Modern machines which combine the sloped-back wing with the negatively disposed tip differentiate themselves naturally into two distinct classes. In one of these is contained all machines of that type which in Austria and Germany is styled 'Zanonia-form,' the other comprises those types with which I prefer to experiment.

"So far as I know, the Zanonia leaf represents Nature's solitary attempt in the Botanical Kingdom at the production of a gliding aerofoil.

"The figure shows a front elevation and plan view of this extraordinary leaf. You will see that the heavy seed-pot is placed right in front of what constitutes the leading edge of this little aeroplane, so as to bring the centre of gravity into the proper position. The wings curve back on either side. As the leaf withers and dries, the tips, which are the rearmost part of the wings, curl up behind so as to present a very marked negative angle of incidence.

"Ahlborn of Berlin was the first to draw attention to the gliding qualities of the Zanonia leaf. Various persons have attempted to embody its characteristics in full-size aero-surfaces, Blériot among the number. Herr Etrich has, however, given the greatest amount of time and attention to the study of this division of the retreating-wing machine.

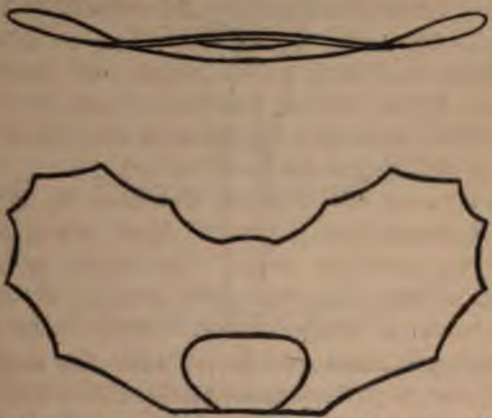

FIG. 31. INHERENT STABILITY. The Zanonia leaf.[1]
("Aeronautical Journal.")

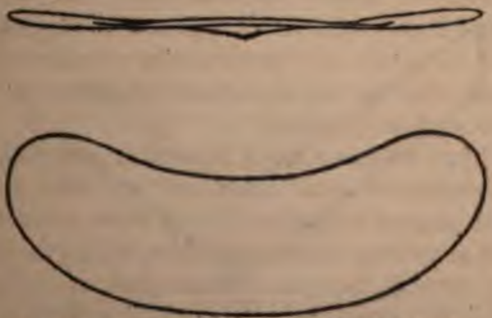

FIG. 32. INHERENT STABILITY. Etrich's system.
("Aeronautical Journal.")

"The figure shows a plan and front elevation of the early Etrich glider, taken from the 1905 Patent. You will see that he has followed the leaf pretty closely. The cross-sections shown in the Patent drawing are nearly

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[[1] *Campelia Zanonia* (order Commelinacaea). Found in tropical America.]

identical with those embodied in the Weiss machin but the Weiss form was more elongated fore-and-a and was, I understand, evolved independently.

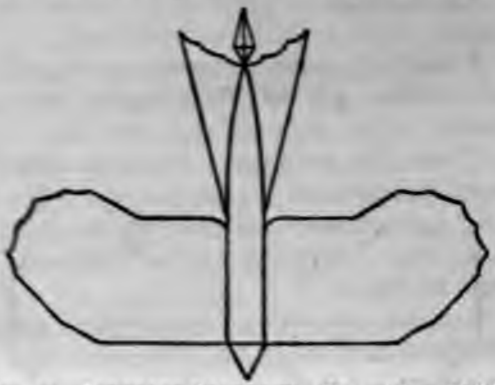

FIG. 33. INHERENT STABILITY. The modern Etrich. ("Aeronautical Journal.")

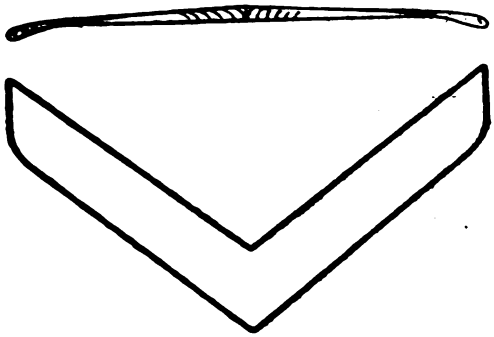

FIG. 34. INHERENT STABILITY. The Dunne system. ("Aeronautical Journal.")

"Later Etrich added a tail, and modified his n wings considerably.

"He has had many followers, particularly in Germ

"Violently opposed to the Zanonia type in r characteristics are the wing forms in the other divi

the retreating-wing, negative-tip group: the division
which I have given most of my attention since 1904."

It is sufficient to record the fact that the Dunne
achine was a success, and that it proved capable of
avelling in a circle with its controls fixed.

Some of the B.E. types of aeroplane designed at the
oyal Aircraft Factory were very stable, and important
chievements in this direction were the R.E. 1 and the
.E. 2c. These did not appear strikingly different from
he ordinary aeroplane to the inexpert eye. The achieve-
ents they marked were described by Dr. R. T. Glaze-
rook, C.B., F.R.S., Director of the National Physical
aboratory, as follows:—

" R.E. 1 marks an epoch in construction, not because
is the first machine which has flown for fifteen minutes
ithout touching the controls—that honour belongs, it is
ossible, to some other machine—but because it is the
rst machine in which the exact balancing of the various
arts has been so calculated as the result of experimental
ork that it shall be inherently stable, and because in
ctual flight it has shown that those calculations have
een verified."

It is necessary to clear away the common error that
ability is synonymous with safety, or is even the chief
ement in security. Stability, being at the best relative,
ay be a positive danger unless it coexists with full
ontrollability. It does not simplify landing or reduce
he amount of skill and experience necessary for that
peration, and reliable motive power remains a prime
ecessity; indeed, the average pilot takes no great
terest in it, and points out that the ordinary well-
esigned aeroplane has a large measure of natural
ability. Pilots have demonstrated this by leaving
he controls of ordinary aeroplanes for appreciable
eriods, and even by getting out of the seat during
ight and climbing out on to the fuselage or the wings.

The value of the stable machine is that it relieves the pilot for other work, as, for example, if he desire to take a photograph or to fire a gun.

Flying has been achieved with very low power. A. V. Roe, in England, flew on a triplane driven by a motor of 9 h.p., and a Wright biplane with a span of 26 feet is said to have flown with 5–6 h.p. These machines were, however, very lightly loaded, and the experiments have little more than historic value. There would be no very useful purpose in continuing them, and aerodynamical efficiency nowadays takes the form of machines that have a low minimum speed combined with other qualities, such as high speed or load-carrying. Efforts have been made to design an aeroplane that will carry a man with the power that he can exercise either by driving pedals or, by some other means, actuating a propeller. It is sufficient here to say that no living man has the necessary strength for this purpose with any known mechanical contrivance; but one would naturally hesitate to assert that this will always be impossible.

Aeroplanes depend for safety, in the event of the stopping of the engine, upon a gradual descent, head dipped. They are then simply gliders; and the aviator's care is to choose a suitable landing-place.

In the construction of a flying machine the running of the craft along the ground, as well as its motion in the air, must be provided for. The machine must be able to endure the strain of a ground speed necessary to flight. Part of its structure provides for the support of the wings when "rolling" on the ground, and part provides for the dependence of the whole machine upon the wings when in flight. The latter, if consisting of wires, is known as the "flight wires," as against the "landing wires."

The propeller is really a revolving aerofoil, or "plane." If in front, the machine is called a "tractor," if behind, a "pusher."

The "pitch" of a propeller is the rise in one complete turn, or the distance it would advance in one revolution, provided it revolved in an unyielding medium. Air-propellers are in effect simply aeroplanes revolving. Their "pitch" and angle are like the tilt and the curve of the planes of a flying machine.

The efficiency of a machine should be judged by its capacity for transporting the greatest load in the shortest time for the least expenditure of power, but very often in open aeroplane speed contests the prize is awarded to the least efficient machine. For example, of two machines in rivalry one carries a load of 1000 lbs. at forty miles per hour with a 50 h.p. engine, while the other carries 600 lbs. at sixty miles per hour with a 100 h.p. engine. It is easy to see that the first is not only more efficient, but it is more economical: the reduction of engine-power means a saving in initial cost and in running-power. The high-power craft, however, usually wins an open speed competition. Of more service to aviation, though not so popular as open races, would be maximum and minimum speed contests. A new feature, introduced in 1914, for the Gordon-Bennett required that competing machines should be able to fly at a certain minimum speed.

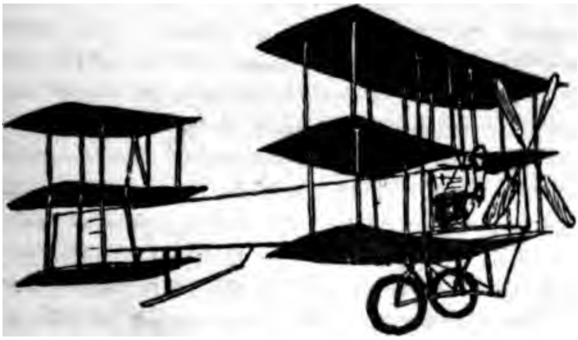

Fig. 35. A Triplane

These considerations are important in view of the fact that much power is wasted in producing mere speed. This has been shown in numberless instances, of which one will suffice. Of two Deperdussin monoplanes flying in a race one was driven by a 160 h.p. engine, the other by a 100 h.p. engine. The former weighed 1200 lbs. all on, the latter 1000 lbs. The 160 h.p. machine which carried 200 lbs. greater load than the other was only two miles per hour faster. The extra 60 h.p. was therefore needed chiefly to lift the extra weight.

While this book is in existence it is safe to say finality in aeroplane design will not be reached. As to future probabilities of development more will be said in a later chapter. Here it will suffice to indicate briefly a few of the chief considerations when designing an aeroplane of any type for any specific purpose.

The form of the wings must be chosen, and even in wing-sections it cannot be said that no progress remains to be made. The lift and the drag of the wings, the head-resistance of every part of the structure—fuselage, landing carriage, struts, and wires—must be calculated. And these depend upon the speed; and the speed depends upon the power of the engine.

To a great extent the machine must be designed round the engine, and when it comes to designing for two or more engines, for two fuselages, and for seaplanes the details increase tremendously.

In the designing of a quite ordinary single-engine aeroplane, from 150 to 250 large working drawings have to be made, and reams of calculations. In short, it is not possible, as in the early days of flying some people appeared to believe, to sit down overnight, think out a new flying machine, and make it the next day.

CHAPTER IX

SENSATIONS DURING BALLOONING

In this chapter and the next an attempt is made to convey to the reader who has never actually ascended in any aircraft a clear impression of the sensations of aerial travelling. Dealing first with ballooning, quotations from writers who have taken pains to describe their sensations are given, beginning with an extract from Monck Mason's "Voyage of the Great Nassau Balloon":—

"The conveyance through the atmosphere by means of the balloon is a thing so entirely *sui generis*, so essentially distinct in all its bearings from every other process with which we are acquainted, that no force of reasoning is of itself capable of awakening in the mind of an utter stranger to the art, any adequate notion of the peculiar phenomena which characterize this novel and interesting mode of transport. So devoid, indeed, may it be said to be of any of those analogies which in other matters serve to supply the place of actual experiment in determining the general results of new and untried combinations, that I am convinced that if an individual were to set himself down with the intention of endeavouring to picture in his imagination the various circumstances and impressions which develop themselves in the practice of aerostation, with all the advantages which a thorough knowledge of the arts and sciences in general could contribute to his assistance, he would still arrive but at a very rough and imperfect representation of the real nature of the case in question.

"The first thing, then, which strikes the incipient aeronaut in the outset of his career is the sense of extraordinary quiescence which immediately ensues upon the dismissal of the machine from the ground. No matter how agitated the balloon before its departure, no matter how violent the circumstances under which the ascent is effected, the moment the hold upon the solid earth is cast off all is perfect repose and stillness the most profound. The creaking of the car, the rustling of the silk, the heavy lurching of the distended sphere, swayed to and fro by the breeze, and shifting its load with sudden and energetic motion, despite the efforts of the individuals who are struggling to retain it, all have ceased in an instant and are succeeded by a degree of tranquillity so intense as for a moment to absorb all other considerations, and almost confuse the mind of the voyager from the suddenness of the change and its apparent incompatibility with the nature of the enterprise in which he is embarked.

"Recalled to the knowledge of his situation, a sudden and most natural impulse at first leads the aeronaut to look forward. Nothing, however, appearing in the direction in which habit has almost unconsciously impelled him to direct his gaze, his eyes insensibly assume a downward course, and he becomes at once assailed with a mass of observations and reflections, among which astonishment at the unusual tranquillity that accompanies alterations so rapid and so remarkable is one of the most prominent. Without an effort on the part of the individual, or apparently on that of the machine in which he is seated, the whole face of nature seems to be undergoing some violent and inexplicable transformation. Insensible of motion from any direct impression on himself, and beholding the fast-retreating forms, the rapidly diminishing size of all those objects which so lately were by his side, an idea almost amounting to conviction involuntarily seizes upon his mind that the earth, with all its inhabitants, had, by some unaccountable effort of Nature, been suddenly precipitated from its hold, and was in the act of slipping away from beneath his feet into the murky recesses of some unfathomable abyss below. Everything, in fact, but himself seems to have been suddenly endowed with motion.

"He becomes gradually struck with the extraordinary degree of ease wherewith he feels himself able to regard his situation, and the total absence of all those sensations of giddiness and mental anxiety which he has always felt and conceived inseparable from positions apparently analogous to that which he at present occupies. Instead of shuddering, as he might fairly be supposed inclined, at the prospect so unusually placed before him; instead of drawing back, as it were, into himself to escape the full acknowledgment of the precariousness of his situation, he is astonished to find himself intently poring over the new leaf in the book of Nature which triumphant art has just enabled him to peruse, and, far from trembling at its contents, enjoying in perfect tranquillity of mind the wonders it is continually unfolding to his view.

"Nor is this a privilege by any means restricted to solitary cases, or dependent in any way upon the physical or mental constitution of the parties by whom it is experienced. All sorts of persons of every age and sex, and with every imaginable distinction of character endowed—the bold and the faint-hearted, the strong and the weak, the healthy and the infirm—equally concur in acknowledging the exemption; nor have I ever met with, nor heard of, any one of the numbers who have hitherto made practical trial of the fact that ever complained of having been afflicted with the slightest giddiness or sense of personal anxiety from their exposure to a situation which, in the commencement at least, must have been equally unusual to them all."

Glaisher records the ascent in which he attained an altitude of six miles. After describing the first part of the voyage, he continues :—

"We are now far beyond the reach of all ordinary sounds from the earth. A sea of clouds is below us, so dense that it is difficult to persuade ourselves that we have passed through them. Up to this time little or no inconvenience is met with, but on passing above four miles much personal discomfort is experienced—respiration becomes difficult, the beating of the heart at times is audible, the hands and lips become blue, and at higher elevations the face also, and it requires the exercise of a strong will to make and record observations.

"Before getting to our highest point, Mr. Coxwell counts the number of his sand-bags, and calculates how much higher we can go with respect to the reserve of ballast necessary to regulate the descent.

"Then I feel a vibration in the car, and, on turning round, see Mr. Coxwell in the act of lowering down the grapnel, then looking up at the balloon, then scanning the horizon, and weighing apparently in his mind some distant clouds, through which we are likely to pass in going down.

"A glance suffices to show that his mind is made up how much higher it is prudent to go, and how much ballast it is expedient to preserve.

"The balloon is now lingering, as it were, under the deep blue vault of space, hesitating whether to mount higher, or begin its descent without further warning. We now hold consultation, and then look around, giving silent scope to those emotions of the soul which are naturally called forth by such a widespread range of creation.

"Our course is now about to change, but here I interpose with 'No, no; stop. Not yet. Let us remain so long that the instruments are certain to take up their true readings, so that no doubt can rest upon the observations here. When I am satisfied, I will say, Pull.'

"Then we wait in silence, for we respire with difficulty and talk but little—in the centre of this immense space, in solitude, without a single object to interrupt the view for 200 miles or more all round, upheld by an invisible medium, our mouths so dry we cannot eat, a white sea below us—so far below we see few, if any, irregularities. I watch the instruments, but forcibly impelled again, look round from the centre of this immense vacuity, whose bounding line is 1500 miles, including an area of 130,000 square miles."

Then the descent: "On nearing the clouds, we observe the counterpart of our own balloon reflected upon them, at first small in size, momentarily increasing. This spectral balloon is charming to look upon, and presents itself under a variety of aspects, which are magnified or diminished by the relative distance of our balloon from the clouds, and by its position in relation to the sun, which produces the shadow. At midday it is deep down, almost underneath; but it is more grandly defined towards evening, when the golden and ruby tints of the declining sun impart a gorgeous colouring to cloudland. You may then see the spectre balloon magnified upon the distant cloud-tops, surrounded with three beautiful circles of rainbow tints. Language fails utterly to describe these illuminated photographs, which spring up with matchless truthfulness and choice decoration.

"Just before we enter the clouds, Mr. Coxwell, having made all preparations for the descent, strictly enjoins me to be ready to put up the instruments, lest, when we lose the powerful rays of the sun and absorb the moisture of the lower clouds, we should approach the earth with too great rapidity.

"We now near the confines of the clouds, see the spectral balloon approaching us, nearly as large as our own, and just then dip swiftly into the thickest of them. We experience a decided chill, and hear the rustling of the collapsing balloon, which is now but one-third full, but cannot see it, so dense is the mass of vapour. One, two, three, four, or more minutes pass and we are still in the cloud. How thick it must be, considering the rapidity of the descent."

The landing is typical: "We are but a few hundred feet from the earth, when Mr. Coxwell requests me to put up the instruments, and he will keep on that level till I am ready. He throws out a little more sand, and I pack up the instruments in their wadded cases. Mr. Coxwell's eye is on the balloon—the course it is taking with respect to the inclination of its descent on the spot where he has chosen to land. Shortly he calls out, 'Are you all right?' 'All right,' I respond. 'Look out, then, and hold fast by the ropes. The grapnel will stop us in the large meadow with the hedgerow in front.'

"Sure enough the grapnel catches in the hedge, and once again we are connected with the earth by one link. The valve-line is drawn, and a little gas is allowed to escape. The sheep which have been watching the descending balloon huddle together and run away, and the cattle, becoming very frightened, place their tails horizontal, and wildly scamper off in all directions.

"Villagers break through the hedges on all sides, and we are soon surrounded by an agricultural crowd, some of whom take hold of the rope attached to the grapnel, and, as directed, pull us down, or hold it whilst we float to the centre of a field. The valve is again opened; gas is allowed to escape by degrees; nothing is allowed to be touched till the reduced buoyancy of the balloon permits the removal of the instruments. The car is gradually lightened, till finally we step out."

The extent of the views obtainable from a balloon is limited by the amount of haze or mist in the atmosphere.

To a man standing on the seashore the horizon is 3¼ miles distant. A flag on a mast 45 feet high and twelve miles distant appears to be on the edge of the horizon.

At the height of one mile in perfectly clear weather, the balloonist should, theoretically, see about ninety miles in any direction. Thus, the tops of the Alps would be seen from an elevation of 10,000 feet over London. But the air is never so clear as to give such extensive vision. Balloonists over London, however, frequently see the sea.

As the balloonist reaches the higher altitudes, the sky becomes of a deeper blue, and the sun appears like a glaring disc on a dark background. Beautiful phenomena are seen by the balloonist. Halos round the sun and moon, rainbows, "glories," or "aureoles"—the coloured rings seen round the shadow cast by the balloon on the clouds—and splendid seas of rolling cloud above and below, reward his enterprise. But the subject is inexhaustible. No two voyages are alike. The following is taken from the author's description, in the *Daily Graphic*, of a night ascent from London:—

"For some moments our eyes were riveted on the Crystal Palace, where our friends were now watching us, some of them probably feeling anxious on our behalf. Soon the lights of the Crystal Palace could not be distinguished from the myriad lights stretching away on all sides to the horizon. The lights of London's 150 square miles were displayed below us, infinite in degrees of colour, brilliance, and arrangement. Overhead the stars completed the picture. It was as if we were poised in the centre of a vast illuminated globe, whose dark sides were frosted with silver and gold, the roof glittering with lights of peculiar beauty, and adorned with the crescent moon, now hanging over the south-western horizon."

Over Essex at night the silence was broken only by the barking of dogs and the occasional whistle and rattle of a train. Suddenly a voice hailed out of the darkness, sounding very near. The balloon had descended near the earth without the aeronauts perceiving it, and quickly they shouted, "Where are we ?"

"Going towards Dunmow," came the instant reply.

Later on, over the North Sea, and crossing 360 miles of it: "At ten minutes to one we became aware of a sudden change in the conditions around us. As if by magic, summoned to appear out of the void in all directions, at a great distance from us, but about the same level, a great number of small, white, fluffy clouds appeared. The circle was complete. It seemed as if the demonstration must be intended for us. Then we became aware that similar clouds were forming another ring nearer to us. Quite motionless in relation to ourselves these weird shapes remained. They were travelling in the same wind. As for our progress, no sense of motion was perceptible. Not a tremor of the car, not a breath of wind, yet we were going at thirty-five miles an hour."

In another voyage the sea was crossed by day.

"Sea everywhere, and no land in sight. The tens of millions of waves looked very diminutive, but crystal clear, and reflected from their facets every degree of grey and green, light and shadow. The sea was not rough, but the tops of an infinite number of waves were broken to snow-white foam. As we descended nearer to it the incessant murmur of the commotion of waters reached us—a sound of unique quality and wonderful sweetness."

Dawn in cloudland is nearly always impressive.

"At five o'clock the light was strong enough to make a faint shadow. The balloon had fallen to 4500 feet. The cloud scenery now began to bestir itself and commenced a series of wonderful groupings. Across the north-east a straight row of weird and fantastic shapes appeared, black as ink against the lightening sky. They resembled gigantic trees rearing themselves from a flat land covered with white mist. These grotesque shapes appeared to be the same clouds that half an hour before had passed slowly below us, then appearing indefinite and fleecy.

"The dawn grew nearer, and a red tinge appeared behind the row of cloud-trees, which became blacker and more sharply defined. A beautiful green hue appeared above the red. To the south the clouds were bluish grey. The stars were still very brilliant.

"Almost suddenly, at about six o'clock, the row of strange trees lifted up to a higher level. Imperceptibly the tree-clouds disappeared, and a series of mysterious and ever-changing clouds took their place. One slate-grey, ponderous-looking mass occupied a giant's share of the northern sky slightly below us, but with its topmost peaks and domes far above.

"It is impossible to give any idea of the immensity and variety of these changing scenes. Nothing like them could be seen from the ground. In the south a limitless stretch of cloud-peaks look like Switzerland moulded in snow. The impression of distance conveyed by it was wonderful, and probably the view extended to 150 miles or more of cloud."

Infinite is the variety of cloudland. Here is another dawn :—

"Across the light in the east regiments of vapoury figures slowly stalked. It was easy to imagine that these grotesque shapes were inhabited by spirits akin to their weird forms. There was strange commotion in the field of grey fog. Wisps of thin cloud would suddenly rise here and there, and as the light increased the cloud-shapes became better defined. Never at rest in the general movement eastward, varying currents of air carried some portions of the cloud area faster than others. There were other movements of the irregular surface up and down. The woolly hillocks passed and repassed each other, rose and fell before each other, and, against the background of the lightening sky, they appeared like small moving pasteboard targets in a shooting-saloon, only white and soft-edged like frisking lambs."

Passing over Germany at night :—

" At a distance villages and towns were mere blotches of milky light in the darkness. As we approached one it would slowly grow, the blur resolving itself into a group of tiny points of light, becoming larger and larger, and developing in character every minute. In the case of a large town the effect was very striking. What had appeared a small blur of light would extend until it covered half the visible area below with lights of every possible shade of yellow and white and the bluish white of electric lamps.

" Later the country seemed to be almost deserted. Only occasionally could we hear the barking of a dog or the roar of a train. When above the clouds silence seemed absolute. We appeared to be going in the same direction as the clouds below, only faster than they. It was a curious race between the balloon and the patches of vapour, and the balloon never failed to overtake and pass any point in the diversified field of grey upon which we set our eyes. At rare intervals through an interstice in the clouds we caught a glimpse of a cottage light."

During a night voyage over England the author had a remarkable experience, the balloon disturbing a vast number of pheasants, partridges, and water-fowl, whose strange shrill cries and the rushing of myriad wings amounted to a deafening volume of sound. Dogs barked, and the tinkling of sheep-bells and the trampling of horses over turf could be heard. Coveys of partridges created sudden disturbance as the balloon neared them. We heard the peewits' shrill calls and the alarmed twitter of many small birds. It was interesting to observe that the perfectly silent passage across the sky of the balloon was sometimes sufficient to arouse these sleepers. The balloon became enveloped in thick fog, and we could not see any habitation, but once the sound of a man's cough was heard and there was an incessant twittering of small birds and the calls of water-fowl.

It is impossible to describe the innumerable small entertainments, and the constant anxiety of a night in the air under these circumstances. Fog is the balloonist's paricular enemy, and although fortunately not imperilled by it, the occasion in question caused much anxiety. Fog All around, above and below, and suddenly, close to one's lbow, as it seemed, the bell of a church clock chimed hree o'clock. There was the constant inquiry, "Is our course the same?" and the eager watching for a momentary clearing of the fog in which to take an observation.

Aerial travellers will be out in all weathers. Here is he description of a cold night over Russia :—

"We were huddled up in corners, keeping our electric amp ready for reading the aneroid, the glass of which was coated with ice, which had frequently to be rubbed off. Our caps and coats were thick with snow, and altogether a colder and gloomier aspect of affairs could scarcely be imagined except in the Arctic Circle. Steadily we climbed to 11,000, 12,000, 13,000, 14,000 feet, each thousand taking no more than ten minutes to accomplish. As steadily the thermometer went down to 5° Fahr. Fifteen thousand, 16,000 feet high, and the thermometer down to zero, beyond which point it would not indicate, for so great a cold had not entered into our calculations.

"Even at this height the snow was falling. Through 16,000 feet we had forced our way upwards against it, in spite of our increasing burden. Less rapidly the aneroid indicated that we crept up to 17,000 feet, and 200 feet above that—17,200 feet—and the temperature probably at least 2° Fahr. below zero.

"I think we were all worn out by the exposure and the hardships, and it is likely enough that the rarity of the air at this altitude of over three miles—higher than the highest mountain in Europe—may have distressed us a little. It was easy to imagine strange forms in the blackness, out of which streamed cold, light particles touching our faces and clinging to our clothes: there a gigantic monstrous shape floating by; below, a dimly-seen palace, and a woman descending its marble steps, finding her way by the light of a lamp."

No apology is needed for quoting so extensively the experiences of balloonists in the clouds. The object in doing so is to convey to the reader a clear impression of life in the air. They apply, with certain modifications, to mechanical flight.

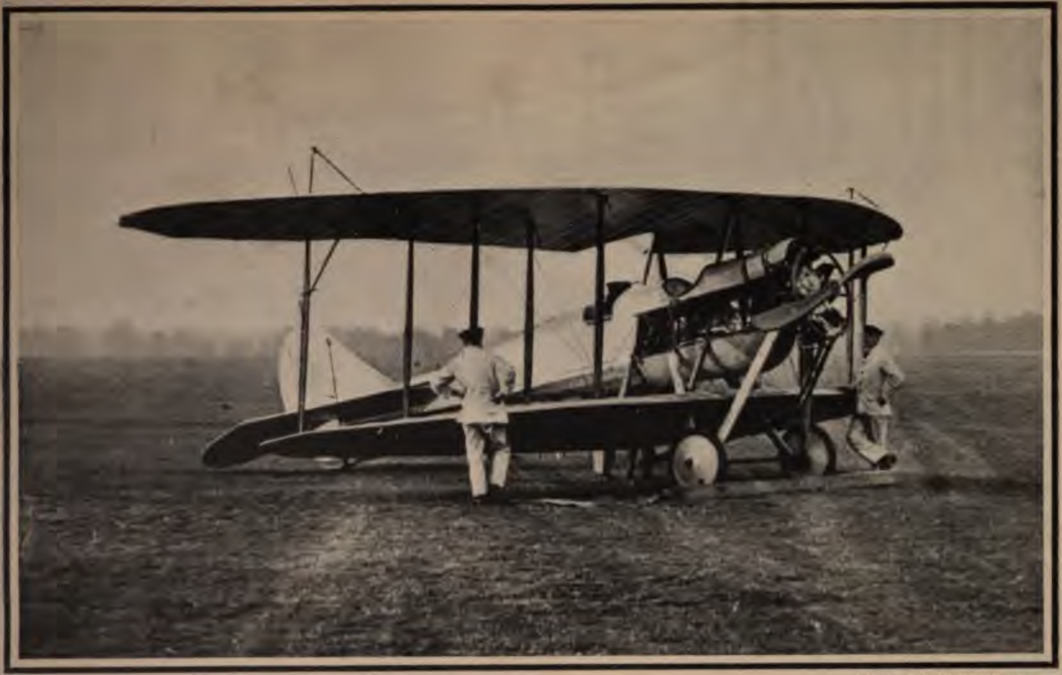

Photo: Mr. R. B. Munday

A British Self-righting Aeroplane

The Handley Page Biplane, an inherent stability type.

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CHAPTER X

SENSATIONS DURING FLYING

Some of the experiences recorded in the previous chapter are similar to those felt in a dirigible balloon or a flying machine. Dirigible balloons being but little used for other than military purposes, there is not at present any extensive literature of a descriptive nature to draw from. An ordinary balloon travels with the wind, and it is unusual for a breath of moving air to be felt in it. Wind, however, is one of the greatest elements in the traveller's sensations in a dirigible balloon or an aeroplane. In the latter even on a calm day the traveller is, relatively speaking, in a gale, for the speed is forty miles an hour or more. An airship frequently has a seesaw motion, and there is considerable vibration from the engine—so much vibration that it is almost impossible to read the instruments, and the noise is deafening.

But let those speak who can do so from actual experience. From Emil Sandt's description in the *Daily Mail* of a voyage in a Zeppelin airship, the following is quoted :

" There are moments when, sailing full speed, a headwind blowing at thirty miles an hour holds us so firmly that we cannot make more than a foot of headway. Deep below, upon the sunny, rocky surface of the earth, I observe the shadow of our ship as she painfully essays—one might almost say inch by inch—to advance. Above, the giant propellers revolve around their axes at such a mad, deafening speed that they resemble immobile glittering discs. From them the sun reflects shimmering copper-red rays, through which one now and then can peer as through a veil. Further along the horizon snow-white clouds take their envious way—envious, because they must go where the wind listeth. We bid the wind defiance or overwhelm it. We go where we please.

"As I now look below, our shadow glides faster over meadows, lakes, houses, villages, cities, forests, and, as we emerge from the narrow passage into which the cross-wind has churned and pressed itself, this gigantic shadow sweeps over the kaleidoscopic landscape with the velocity of an express train.

"I scramble from the saloon amidships. Through its side-walls and floor one has a view which, because of its uniqueness, never loses its fascination. I climb into the after-car of the ship. A long, high, secure passage-way, shut off on the sides with balloon-cloth, leads to a slanting aluminium gangway, and thence into the car below.

"Here unfolds itself for the first time the full panorama of the world below, around, and above us. For a fleeting moment I try vainly to combat the temptation of omnipotence; for a second I am overcome with the intoxicating consciousness of sovereignty in the supreme degree—of mastery over height and space—mastery over depth and time.

"We cross the Lake of Lucerne. Pilatus greets us from the west, Rigi from the south. Over Kuessnacht we glide across the mountain ridges, playfully negotiated, to the Lake of Zug. Thence, in circumstances of extraordinary difficulty for testing the dirigibility of our craft, to the Lake of Zurich. Here a wonderful view awaits us. Below is the emerald-green lake, which, when we look, reflects our airship with brilliant clearness—a soft-bordered, deep-green shadow on a liquid field. Now we cross Switzerland, via Winterthur and Frauenfeld, and then take flight for the Lake of Constance over Roschach, Bregenz, Lindau, Wasserburg, back to our home port, after a trip lasting more than twelve hours, with a crew which is still fresh and machinery which has obeyed the slightest command."

The author's first passenger flights were made at Brooklands and at Hendon towards the end of 1910, when he took his first photographs from an aeroplane. The first cross-country flight is always a great experience. In the author's case it was over Salisbury Plain, taking in Stonehenge. As he wrote at the time, the circumstances that placed one of Great Britain's first aviation centres in sight of Stonehenge, that mysterious monument of ancient times, must surely have been something more than chance. So dramatic and romantic an encounter between the ghostly past and the mightiest and most modern of scientific miracles might well have been arranged by a supreme artist weaving strange pictures in the loom of time. The machine sped swiftly through the air some hundreds of feet directly over Stonehenge. Behind, the roar of the Gnome engine that impelled the machine; around, the buoyant wings obeying the lightest touch of the pilot's hand; and, tearing past like a gale of wind, the frosty air that held the machine up yet seemed to strive its utmost to bar its way. Towards the end of the journey Archibald Low, the pilot, stopped the engine and brought the aeroplane down in a steep vol plané to a lower altitude, approaching a flock of sheep, who scattered wildly. Then he started the engine again, and resumed skimming along a few feet from the ground.

In an aeroplane there is no sense of height except that deduced from the apparent size of familiar objects. The rush of wind is ever on the face, and in cold weather it is very cold indeed. But always it is exhilarating.

When the engine starts the noise, vibration, and sense of speed as the machine shoots forward over the ground are at first rather alarming. It is almost impossible to perceive the exact moment that the ground is left; only there is, with the increased speed and when flying, a rapid diminution of the noise, a swift decrease of the vibration, until the machine is simply gliding with perfect smoothness and there is no sense of speed except the rush of wind. As the ground is left it no longer continues to rush past, and the higher the flight the slower the apparent motion. As to one's sensations in full flight, there is the growl of the engine, which, with use, becomes less noticeable, and with this there is the rush of air over the planes giving forth its own peculiar music. Sometimes the machine rocks slightly laterally and in the path of flight, but the movements are as a rule very small and are corrected as soon as they occur. Occasionally, too, the machine will seem to sink slightly and suddenly in what is known as "a hole in the air"; and at times one hears a slight thumping as with a muffled mallet on the planes, caused by the buffeting of the air.

Frantz Reichel, writing in the *Figaro*, recorded his impressions in the following manner:—

"I have known to-day a magnificent intoxication. I have learned how it feels to be a bird. I have flown. Yes, I have flown!

"I am still astonished at it; still deeply moved. For nearly an hour I have lived that daring dream vainly pursued through all the ages by audacious man.

"When we started there was a sudden impression of a plunge into space which gave me a *coup à l'estomac*. Then suddenly it was all very smooth, a cradling amid the thunder of the motor. I did my utmost to see well, to feel everything radiant, but not daring to move or even to stir.

"We advanced towards the horizon, the dunes, the hills, the fir-trees, in a giddy gliding. It was strange and exquisite. The air flowed upon me caressingly. I could keep my eyes wide open; the air bathed me but did not whip me. This was the first impression a mile from the starting-place, above a magnificent carpet of heather.

"I hung out my head and looked at the crowds below. They were waving handkerchiefs. Gently, with my elbow firmly fixed to my side, I moved my arm in a mechanical manner, like a dummy. I let go of the iron bar by which I was supporting myself. It was quite safe to move, and I risked more and more.

"The sun is sinking, we are flying in the twilight. From the ground appears and descends a slight mist, which covers the big glens with a white carpet. It is the doubtful and suspicious hour of the day.

"The night has come. It is getting dark, and the moon is rising. Silence reigns over the woods and fields. I cannot believe that it is I who am flying in the night. The sensation is so magnificent that I long to pass several hours in such a manner.

"Night is now complete. Cyclists, peasants, and chauffeurs have lighted their lanterns or their torches. And this illumination pierces through the darkness. But we fly on, chasing our shadow, which the moon throws before us.

"If I had known I should have brought a pencil and a writing-block with me, and have recorded my impressions. One is able to write much more comfortably in an aeroplane than in a train or motor-car."

A blind man after enjoying a flight with Gustav Hamel said :—

"I felt as though I were on the back of some great sea-gull, flying through a dense mist. Blindness is oblivion, but when I was up in the air I felt mist, not darkness."

The wind astonished him, but most of all the power of the airman to conquer it. "A man driving the machine," he added, with a little touch of envy, "must feel like a god."

A correspondent related in *The Times* details of an interesting description of what he terms "psychology of a war flight" given to him by an airman.

From the point of view of a medical man, it showed (remarks the writer) in what a remarkable way the nervous system is capable of adjusting itself to new and severe conditions and of preserving its balance even when hope of salvation has been abandoned.

The airman received orders to go to a particular place and there drop bombs. Shortly after setting out the zone of fire was entered, and in order to avoid mishap it became necessary to take advantage of such cloud cover as could be obtained.

The writer's informant related how he was lost in the clouds, and could not see at what angle he was flying :—

"I pulled the elevator . . . and next moment everything became perfectly silent round about me. I knew then that I had overdone the pull and forced the machine up almost vertically and in consequence had stopped her. And I knew that now she would probably slip back or fall over sideways."

One or other of these two things happened, though the airman could not say which. He gave an extraordinarily vivid account of his plunge through space.

"I felt my holding-in strap tighten, and knew that I was upside-down. It was still as dark as night. I tried to right myself, and failed. I tried frantically. I began to feel that it was all over with me, and I experienced the most acute agony of mind. But suddenly and quite unexpectedly that feeling passed away. I had tried everything and failed. I was conscious of that. Now a wonderful sense of calm took the place of the anguish. It was the most easy and delightful sensation I have ever felt. And meanwhile I was falling, I suppose, at the rate of about 200 miles an hour.

"The next thing I remember is that my holding-in belt burst and that automatically I jammed my knees farther under the indicator board and gripped the seat with my elbows. I had taken my feet off the rudder bar. I was some inches out of the seat, and the machine was upside-down. I only knew it was upside-down in a vague way, because I had left the seat. I was quite happy, and I had no anxiety of any kind. I did not feel anything. Then in a moment the aeroplane fell out of the cloud, and I saw the sea rushing up towards me. My hands automatically moved the controls, and at 1500 feet the machine righted herself. Then at intervals I heard a curious snapping sound in my ears, and realized that I was deaf. I could not hear my own engine."

This deafness was due (comments the writer) to the very rapid descent and consequent sudden increase of atmospheric pressure. It had a psychological effect, for it helped to accentuate the sense of depression which followed the return to safety.

The airman, who had passed from violent agitation of mind to the " calm of despair "—he desired me to emphasize the easy character of this state, which, he said, disproved all he had expected and feared—now suffered a severe sense of shock. But he continued on his way, mastering himself until he was able to launch his bombs.

The first of these achieved its purpose, and he saw that it had done so. Immediately a reaction of feeling set in. He confessed :—

" I was so happy that I shouted. I simply couldn't contain myself. I felt in all my pockets for something else to throw down. All I could find was my matchbox, and so I threw that."

Here the author of this book recalls his own sensations during a looping flight with Gustav Hamel. He noted particularly a momentary feeling of suffocation just before the aeroplane reached the top of the loop. The cause appeared to be the sudden cessation of the rush of air due to the check to the machine's speed after its swift rush downward. Probably if in normal flight anything like the same check to a machine's speed occurred the same feeling of suffocation would be experienced; indeed, pilots who have violently checked speed—apart from looping the loop—may have already felt it. The feeling passed immediately, for directly the aeroplane had passed the top of the loop the speed increased, and, moreover, it seemed a great relief to see mother earth again, notwithstanding the inverted position. Another thing that struck him—but this may have been entirely imaginary—was the acuteness of his vision looking at the ground below while the machine was upside-down. This was probably due to the novelty of the scene, and would pass off after a short time, though he would not care to remain in that position for many seconds. One more impression is, perhaps, worth recording, and that is the tremendous song of the wing stays and wings when plunging down vertically at the termination of each loop before the engine picks up again. It is a glorious mad rush down, provided a first-rate pilot is in charge; otherwise, one would have reason to feel uneasy. The dive must not be continued

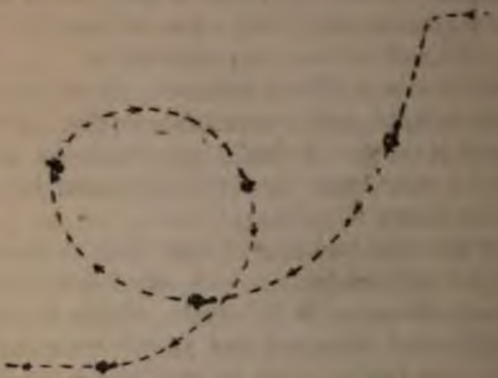


FIG. 36. PATH OF AN AEROPLANE "LOOPING"

too long, and care must be exercised to bring the aeroplane to a level without violence.

As to the actual labour of conducting a loop, the author watched Hamel, and there was certainly no violent work with the controls. It appears to be a question of timing, and of judging speed, and matters of that kind that only come with experience.

No distressing sensations were felt, although Hamel naturally felt a little ill after a quick series of twenty-two loops followed, as they were, by a long tail-dive. The author is of opinion that it was the tail-dive that taxed him. At any rate, it was immediately after it that he complained of deafness and a general feeling of impairment. Surely falling back, with the machine's tail pointing earthwards, puts the pilot into a position unlike that experienced in any other sport; and it must be remembered the tail-dive is a swift reverse of the previous attitude of flight: the sudden change must be distressing. Merely to plunge suddenly into a cloud is sufficient to make an aviator feel slightly giddy. Decidedly the tail-dive—which very few machines are structurally sound enough to endure—is likely to tax a pilot's brain and body unduly, and it is hoped that very great care will be exercised by all who desire to perform the feat. The sudden jerk after tail-diving is distinctly alarming for the pilot, and must be a strain on the machine.

As to the value to the pilot of looping, it is no longer questioned, to say which does not in the least imply approval of making popular exhibitions of it, at any rate to any excessive extent.

Here may be recalled the author's flight with Gordon-Bell from Buc to Whitstable in May, 1913.

"We headed straight across Versailles at a height of about 1500 feet, Paris down on the right hidden in mist, the rising sun above it seen through a maze of dancing light, the land below and to the west clearly visible.

"We mounted steadily to about 2200 feet, at which height we remained throughout the journey except at the Channel crossing, when we nearly trebled it.

"Gradually the sun's increasing power brightened the landscape. We were supremely happy. The wind, although hindering, was steady, and the machine's motion was smooth. We could not converse while the engine was running, but when it was necessary to speak Gordon-Bell cut the engine off for a few moments, and while we planed down a few yards, we talked. For certain things we had signals. I had little to do except watch a gauge and keep an eye on the course. We passed notes to each other occasionally; for example, Gordon-Bell found it easy, while piloting the machine, to write :—

"'This is Meru? How far have we come, and in how many minutes?'

"But it was not all to be plain flying. There came up against us out of the north a legion of small woolly clouds. They became larger and more numerous, and soon we were enveloped in mist. We descended to about 500 feet, and even then the land was barely visible.

"The fog became thicker. We could not follow the route; and, after a little while, steering by compass became too inexact. So we landed in a large field, where were some harmless-looking beasts, who, however, immediately surrounded the strange invaders from the skies.

"They turned out to be young bulls of a most inquiring frame of mind, and for five minutes Gordon-Bell and I defended the machine against thirty of these youngsters. Then farm labourers arrived to help us.

"Later in the day, after two more landings, the journey was continued. We left Le Crotoy at 4.40, and continued our glorious trip along the coast, passing Boulogne and the high-land beyond in excellent time. As we neared Sangatte and Calais we soared upwards to 5600 feet, so that a more extended view could be obtained and a bigger range for a glide down in case of trouble.

"Now the English coast could be discerned, a faint grey line beyond the mists of the Channel. At 5.20 the edge of the French coast lay immediately below, and the sea appeared. Here it was grey, but away in the west, under the sun it gleamed white. Cap Grisnez marked the turn of the French coast on our left.

"The roar of the motor and the whistling of the rigging alone told the story of our progress. So far as the view went we appeared to be hovering in mid-air.

"Imperceptibly the view opened out until I could distinguish tiny lines from the English coast indicating Dover breakwater and pier. The sun was shining through thin clouds.

"Slowly I saw more and more of England, until, when halfway across, the coast from Hastings, round the Nore, and up the Thames Estuary, probably to Tilbury, was visible. Kent lay before us, a dusky grey patch known by its shape. Beyond, the Thames gleamed yellow silver under the sun, and down the Channel the sea was nearly white.

"Last of all we came in for the worst trouble of the day. We ran into two or three violent eddies while flying along the north coast of Kent, and were tossed about considerably.

"Kent looked very verdant and inviting, but we had decided to come down for the night at Eastchurch, on the Isle of Sheppey, which, for half an hour past, had been visible in the far distance.

"The fates were against us, however. At 6.30 the engine stopped dead. I thought Gordon-Bell had switched off, and was amazed when we headed steeply down and the engine remained silent.

"But as we descended swiftly and steeply I realized that a landing was intended—indeed, unavoidable. And here the pilot's skill did him good service. There was plenty of room to land in, but of all the available fields one was the best. It was for that one that Gordon-Bell steered, although it involved a bit of 'trick' steering—a kind of aerial 'Turkey-trot' between some tall trees. A clever bit of work, so clever that the people below made sure they were witnessing an accident."

CHAPTER XI

LEARNING TO FLY

THIS is not a handbook on practical flying, but rather a review of the present position of aeronautics in every aspect. It will, however, be conducive to a right understanding of the subject if the work of the aviator is examined and criticized, as well as the craft he navigates and the principles he studies.

As an introduction to mechanical flying, a brief account will be given of gliding, which in the early days was a preliminary to power flight. Flight on motorless machines may yet have a vogue, and quite possibly the use of engine-driven craft may lead to a knowledge of the principles of flight that will put gliding on a new level. It is of interest to recall the fact that the Wright Brothers did some of their most wonderful glides long after the attainment of full success with a motor-driven aeroplane.

Lilienthal wrote :—

"Let us begin with practice in sailing flight. The apparatus has 107 to 161 square feet superficial area, and weighs about 44 lbs. if built of willow wands covered with calico. The greatest width of the wings should not be over 8·2 feet, and the spread from tip to tip not over 23 to 27 feet, so that the equilibrium may be maintained by a simple movement of the body, altering the balance. A fixed vertical rudder, placed as far as possible to the rear, facilitates steering to left or right. A horizontal rudder prevents tipping towards the front. The apparatus is held fast by seizing it with the hands and laying the lower part of the forearm between cushions, so that the legs remain free for steering, running, or landing.

"The best place for practice is a bare hill with a slope of about 20 degrees in every direction." (Lilienthal practised from the top of an artificial hill.)

"You hold the apparatus inclined towards the front, take a run against a gentle breeze, and, keeping the apparatus horizontal, make a short leap into the air. In landing, the apparatus is to be lifted towards the front to check the velocity. When the operator feels able, the sailing may be gradually extended. If one side of the apparatus is lifted by a gusty wind, the balance must be moved to that side in order to restore equilibrium. The longest sailing flights are obtained when the front edge of the sail-surface lies a very little lower than the rear edge. In a calm the velocity of sailing will be about twenty-two miles per hour, and the gradient will be about 1 in 15 downwards.

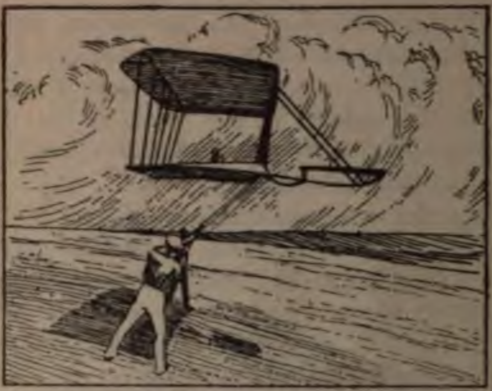


FIG. 37. THE 1900 WRIGHT MACHINE
Soaring in a wind of 35 miles per hour.

"If an apparatus actuated by a motor is to be used, it should, in the beginning, be operated in sailing flight only.

lually, and after a landing can be performed without ble, the propelling portions of the apparatus may be into operation."

ıanute made 700 glides on his biplane glider (see ram 6, page 33) without the slightest accident. Its weight was 22 lbs. To "lift" off the ground the :or had to attain a speed of twenty miles an hour.

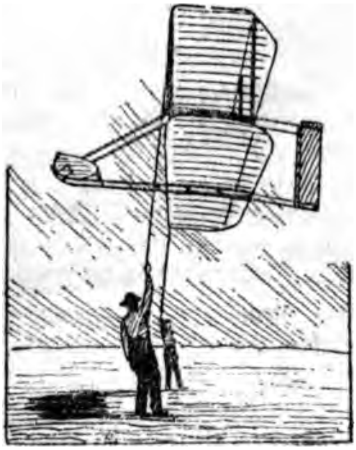


FIG. 38. THE 1902 WRIGHT MACHINE
Flown as a kite in a light wind.

he did by running and jumping off the top of a ad. The angle of descent was about 1 in 10.

ıe Brothers Wright made a great advance on ıute's work. They adopted the prone position in ıg instead of the upright, thus making the landing r, and they used a glider twice as big in superficial as that of any of their predecessors. They discarded :ail seen in the Chanute glider, but used the horiıl rudder (or "elevator") at the front. The Wrights d hundreds of times safely from the top of a hill. steered from right to left by tilting the right and left extremities of the wings. Their glider had a superficial area—that of the two planes combined—of 340 square feet. Its gliding angle was about 1 in 14. On October 24, 1911, Orville Wright, in a motorless machine in a fifty-mile gale at Kitty Hawk, soared for 9 minutes 49 seconds.

Gliding is a sport that does not require great physical strength, but it demands a certain amount of courage. The aviator acquires from gliding, rapidity of decision, accuracy of movement, and an instinctive response to emergencies invaluable to him in the steering of large machines, and although it is very seldom part of the training for flying, the author is strongly of the opinion that the art ought to be encouraged.

Before going further into the question of the practice of gliding, it will be well to describe a simple appliance that could be made by almost anyone. No other materials are required than piano-wire, copper-tubing, calico, iron-sheeting, twine, bolts, and nuts; and the cost need not exceed £2 10s.

Experiments in gliding require a piece of ground having a slope of 1 in 10 or 1 in 8 over a length of from 60 to 120 yards, the slope lying in such a direction that the prevailing wind blows straight up it. The ground should not be in the proximity of trees and bushes. The field need not be more than 60 yards in breadth, but it should not be less. Trials should be taken against the wind, and in a very gentle breeze it will be found that the apparatus will manifest a great desire to rise when held with the long edge against the wind.

Having taken up his position in the apparatus, the experimenter requires two assistants to hold the two lower front corners by means of cords. Then he moves slowly forward against the wind, gradually accelerating speed, and, as experience comes, lifting his feet off the ground, keeping ready to put them down again. He will that the machine will readily lift, and his assistants not have to support his weight. After a few trials he begin to feel at home on the machine, and be able to › his feet off the ground for longer periods. The limit ıe speed at which the assistants can run regulates the th of the flight. As the reader already understands, greater the velocity the greater is the lifting-power. a good wind will provide the pressure of air necessary ive flights of 40 or 50 yards, the aviator's task being ›ly to control the steering, keeping the entering of the machine square to the wind, and in keeping itudinal stability by moving his body backwards or 'ards as required.

'hen sufficiently confident he will give the order to the tants to release the cords, and he will then glide y in the air. The experience gained in early attempts ›les him quite easily to preserve the equilibrium of apparatus. His legs will swing backwards and for- ls almost instinctively. The rudder is actuated by ns of the steering-lines, one of which is held in each l. Contact with the ground at the end of the flight uite gentle; and gradually the excursions can last er.

strongly-built glider will descend with perfect safety ı a great height. For instance, in Montgomery's r an aviator descended from an altitude of 3000

ontgomery, a professor in Santa Clara College, Cali- ia, built a glider, and he found a parachutist, J. M. ›ney, who was daring enough to attempt an unprece- ed feat in gliding from a great height. The apparatus isted of two curved planes placed one behind the r, each 24 feet across and 4 feet wide. The back wing so fastened to the frame as to be capable of being ed by wires in various directions. There were also rtical keel and a rudder plane, the latter being in two semicircles at right angles to each other, made movable for both horizontal and vertical steering.

The machine was raised by a hot-air balloon, and then cut loose. When set free from an altitude of 3000 feet the glider swooped down for a few seconds, and then began to glide at a small angle of descent. By changing the angles of the planes, the aviator could vary his movements; he could glide in a circle, dart steeply down, or even cause the machine to rise a little. After the descent, which occupied about thirteen minutes, the glider alighted on the ground as easily as a bird.

This machine was tested at Santa Clara on April 29, 1905, and was then lifted by the balloon to a height of about 3500 feet. The aeronaut showed that he had full control of it by causing it to soar like a bird, sweep in circles to right or left, or make deep dives. Finally, after a flight of about nineteen minutes, he descended gently in a meadow about a mile from his starting-point. Maloney was afterwards killed in a similar attempt.

Sufficient has been said to indicate the broad lines upon which lessons in gliding should be taken. A very simple apparatus has been described, but there are various other types, and constant practice of a large number of people will, without doubt, result in the evolution of a form superior to any at present in existence.

Coming now to lessons on a motor-driven aeroplane, it is first necessary to describe the controls. Most aeroplanes are fitted with a pivoted foot-bar by which the rudder is controlled, a forward movement of the right foot turns the rudder to the right in order to wheel to the right, a forward movement of the left foot turns the rudder to the left. A pillar surmounted by a handle held in the pilot's right hand, or by a wheel which he can hold by either or both hands as he pleases, controls all other movements. This pillar can be moved in any direction. Its movements to and fro affect the elevator, and in a manner that makes its control instinctive. Thus, if the pilot desires the machine to climb he pulls the lever towards him; if he wishes to depress the head of the machine for descending he pushes the lever forward. To raise the left wing of the machine he pulls the lever slightly to the right, the sensation being that of lifting the left of the machine up. To raise the right wing he pulls the lever away from the right. Many of the movements are combinations of fore-and-aft and lateral, and become small curved turns. After each alteration of the wheel or lever, the control is brought back to the normal position. For example, having once got into the angle desired for descending, the pilot brings the elevator back to the normal position. If it remained depressed the angle of descent would steadily increase and soon become dangerous. The pilot in all these operations "feels" the machine answering to his touch.

The instructor gives his pupil a number of rules before his first solo flight, and it is well for the pupil to learn these rules not only by heart but so thoroughly that he puts them into force almost unconsciously. These rules may be summarized as follows in the form they were received by the author in the course of tuition on a "pusher" biplane now being described:—

"When the machine has attained almost sufficient speed for lifting, gently depress the elevator by pushing the lever slightly forward. This assists the tail off the ground. Then, almost instantly, pull the lever slightly towards you. This lifts the head of the machine and depresses the tail. The aeroplane then rises from the ground. Push the lever forward to normal, and then, in order to gain altitude, again pull it back very slightly, and only for an instant. Continue these movements, ascending by small, almost imperceptible steps.

"While flying, do not watch any particular part of the machine or landscape. Your first inclination will be to keep your eyes glued on the elevator. Keep your eyes on all. Do not look at the foot-lever. Make all the lever movements gently. Correct all deviations from even flight as they occur—do not wait until they become pronounced. But you will find that the machine itself has a large measure of stability, and will almost find its own balance without your help. Never allow the head of the machine to become tilted upwards—this is a dangerous position if it lasts. All movements of the lever from the normal should only be momentary; having made a desired movement, instantly bring the lever back to its usual position.

" At the slightest irregularity in the noise of the motor depress the elevator to descend. (These rules are for pupils, of course.) And having come to the descending angle, return the lever to normal until you are near the ground, when you elevate to bring the machine to the horizontal for landing. Apart from engine trouble, in making your first descent, however, come down gradually, reversing the manner in which you ascended. Skim along near the ground, and cut the engine off to alight. If the engine should stop while in full flight, you must descend vol-plané. At the instant the motor stops push the lever forward hard until the machine is at about 30 degrees, and the elevator is about level with your feet. Do not be afraid of making the downward path steep. There is a wide range in the angle at which you may descend with perfect safety, but the beginner is liable to err in making the gliding path too gradual. The machine will find its own gliding path when you have brought the elevator down and returned the lever to its normal position. On nearing the ground do not be in a hurry to pull the elevator up. Wait until it appears as if the skids are almost touching; then gently pull the lever back, 'feeling' the machine into a horizontal position for alighting.

"All the movements will come perfectly natural to you, and the aeroplane itself will help you.

"In flight, when you find the machine tilted up on your right, press the lever away from you towards that side of the machine very slightly. You will find that this presses the right wing down, and you bring the lever back to normal as the machine gets level. If the nose of the machine dips, pull it up by drawing the lever towards you. If it rises, push it down, by moving the lever forwards. If the left side tilts up, pull the lever over to the left. Never exaggerate your movements. In calm weather you will find that for quite long periods the machine requires very little attention. Of course, you must always be watchful.

"Before making a turn to right or left, increase your altitude, because in all turning movements it is advisable to depress the elevator a little, and the machine falls slightly. For turning to the left, push the left foot forward. This deflects the rudder. For turning to the right, push the right foot forward. In turning it is better to slightly 'bank' the machine up on the outside of the turn. Thus, for turning to the left, while pushing the left foot forward, you bring the hand-lever over a little to the left, returning it to the normal, but then, if necessary, repeating the movement. If you have 'banked' the machine up excessively, stop the turning movement at once with the foot-lever and correct the banking by means of the hand-lever, and bring the head of the machine down.

"And now for a few general rules for pupils. Never attempt to rise during a turn. Never trouble to elevate to recover from 'remous' or from 'holes in the air.' If a side gust tilts the machine up excessively, turn into the wind by steering into it, and at the same time correct the cant with the hand-lever, i.e. if the left wing is forced upwards turn to the left by pushing the left foot forward, and at the same time pull the lever over to the left. In turning in a wind be careful about 'banking.' If the wind is blowing from the outside of the turn 'bank' very cautiously, but if the wind is blowing from the inside of the turn you can safely 'bank' a good deal. Never attempt to land in a side wind of much strength: you can easily see by observing the movement of the ground. If the machine has any sideways motion, turn into the wind until the ground is moving straight towards you; then land. Never land with the engine fully working. Switch off before touching the ground. But you can run along the ground under power by switching the engine on and off alternately (this refers to flight with a Gnome motor). To come to a stop, run on the ground a few yards, and then slightly elevate to bring the tail down, which acts as a brake."

A pupil, who has had a few passenger flights, has no difficulty at all in acting instinctively upon these general rules, although they appear, perhaps, somewhat formidable in print. They apply more or less to all aeroplanes, although the methods of control vary in different machines. They apply chiefly to aeroplanes fitted with the Gnome rotary engine, which has not, like some of the fixed-cylinder motors, a great speed-range. In a Gnome motor, speed can be slightly altered by regulating the supply of petrol; but fixed motors have a wider range of power. One special advantage of the rotary motor is that the pilot having cut off the ignition by means of the switch, can, after some seconds' interval, switch on again.

During his first flight the pupil should not ascend higher than a few feet. He will probably have a very confused idea of it, and it will seem to him afterwards that he has not learned anything at all, and that it was only by accident he escaped a bad smash. This, however, is illusion. He has instinctively put into practice all he has been learning, and after two or three flights will begin to feel quite at home in the air.

The greater number of the rules given above apply equally to tuition on monoplanes or biplanes, but in the case of the monoplane, and biplane also if a tractor, it is more necessary to be able to run the machine about the ground with something like accuracy of direction; indeed, a pupil who can control a monoplane on the ground has more than half learned to fly. The biplanes of the slower kinds are far more easy to manage in this respect.

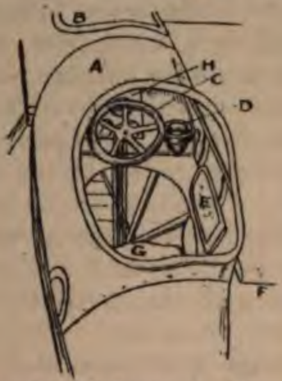


FIG. 39. PILOT'S SEAT IN A MONOPLANE

A. Fuselage. B. Passenger's seat. C. Wheel for "warping" and elevation. D. Compass. E. Map case. F. Rear edge of wing. G. Pilot's seat. H. Instrument board. The diagram does not show the pivoted foot-bar for steering.

It is not at all easy for a beginner to "roll" a monoplane in a straight line. His mount has a tendency to go in any other direction than the desired one, and the curious thing is that movements of the rudder do not affect the machine immediately, but are obeyed after a few seconds taken, apparently, for consideration. The direction of the machine is easier to control when it is travelling at a good speed than when it is going slowly, for the rudder has only full effect when it bears upon the wind with considerable force. Most monoplane pupils have sundry small or large breakages during rolling practice, for the machine, until thoroughly mastered, has a way of spinning round in a small circle or slipping side ways.

As soon as the pupil has mastered the art of rolling and can go from one side of the ground to the other and back in a straight line he is ready to make his first "hop," but he must not, on any account, attempt a turn in the air, nor must he fly higher than a few feet. He must be strictly ordered to alight with plenty of room to spare in order to come to a stop before hitting a fence or any other obstacle. He will, by degrees, be allowed to fly higher in straight lines until he gains confidence to make a half-turn. He will probably have been practising on a "school" machine driven by an engine only just powerful enough to lift it off the ground, but not suitable to make a turn in the air. Foolhardy pupils have, however, in defiance of their instructions, attempted to turn at the second, third, or even the first flight, with an underpowered machine, with the invariable result of a bad smash.

Every pupil must remember that he must never switch off the engine when he is in difficulties of any kind, for that causes loss of speed and controllability. The beginner usually has a strong inclination to switch off when he is in "a tight corner" of any kind. Yet should a smash be absolutely certain it is of the greatest importance that the motor should be stopped before the impact, otherwise the wreck will be all the greater, and more dangerous because of the revolutions of engine and propeller; and, what would be even worse, if the petrol tank burst, and the pilot were pinned down, it is extremely probable that the petrol would be ignited by the magneto and the pilot burned before he could be rescued.

A common method of tuition is on machines with dual control, the pupil using one set, the instructor the other, and the latter being able to correct the pupil's errors and so gradually accustoming him to the work.

If a pupil desires to become a good flyer, and makes good use of his time, when he is ready to take his certificate he has learned many things besides piloting his machine, such as little practical points of adjustment, attention, and repair.

There appears to be very little age limit to the ability to fly. Brigadier-General Lewis Hale, C.B., learned to fly at sixty-two. S. F. Cody learned when he was well over forty-five, and became one of the best aviators. Extreme youthfulness is usually a drawback, since the flyer requires a large measure of caution, sound judgment, and self-control. Probably the best age to learn to fly is between twenty-one and thirty, but the art is not difficult, and is within the power of persons below and also of those a great many years above this range.

The aviator must have the habit of instant decision. This quality must be so strong that it will seem often that he foresees difficult situations and has already taken proper measures by the time they arise. The quality is quite common. The author is convinced from long observation that most men possess it—particularly all sportsmen and those who play games or do things; and by that is not meant merely exercises that cultivate the muscles. It goes without saying that a flyer should not dull his faculties by excesses.

The instant choice of a landing and the nice achievement of it are among the principal arts required of an aviator. When the engine stops from any cause the aeroplane becomes a glider, and must come to ground. Then,

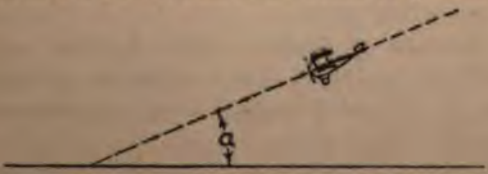


FIG. 40. A STEEP GLIDING PATH

a. The gliding angle.

the better the gliding angle the greater will be the machine's radius. In the British War Office aeroplane trials, 1912, it was required that competing aeroplanes should have a gliding path of at least 1 in 6; that is to say, a machine commencing to glide from a height of a mile must travel six miles laterally before touching ground. A gliding path of 1 in 8 is now common.

Here is a table showing the radius of glide of 1 in 5.

Height. Feet.	Distance. Miles.
500	·47
1000	·95
2000	1·89
5000	4·95
1 mile	5·

The dangers of flying arise nearly always from carelessness or ignorance. The causes of accidents, where they lie in faults of the flying machine and imperfections in the engine, are rapidly being overcome. Those due to bad flying are becoming rarer and fewer, owing to the greater general stock of experience. The personal factor, however, whether of the aviator or of his assistants, must always be watched.

Illustrating the decrease of accidents the following very complete analysis of the flying at Johannisthal in 1911–1913 is here quoted from an article in the *Aeroplane* of March 8, 1916.

Number of days on which flying occurred: 1911, 289; 1912, 317; 1913, 336.

Number of flights performed: 1911, 7,489; 1912, 17,651; 1913, 36,817.

Total duration of flights: 1911, 821 hrs. 41 mins.; 1912, 1,966 hrs. 3 mins.; 1913, 4,096 hrs. 48 mins.

Number of aviators who have taken certificates: 1911, 47; 1912, 98; 1913, 172.

Aviators who have made long flights: 1911, 45; 1912, 84; 1913, 212.

Distance covered in kilometres: 1911, 57,522; 1912, 157,284; 1913, 327,760.

Number of flights which have caused accidents: 1911, 119; 1912, 165; 1913, 320.

Percentage of ditto: 1911, 0·84 per cent; 1912, 0·61 per cent; 1913, 0·31 per cent.

Number of fatal accidents: 1911, 5; 1912, 5; 1913, 12.

Percentage of ditto: 1911, 0·066 per cent; 1912, 0·028 per cent; 1913, 0·032 per cent.

The figures show an enormous increase in the duration of flights, although strangely enough the number of aviators who passed their brevets there was not so great as one would expect. The percentage of accidents seems high, but it must be remembered that the Johannisthal aerodrome existed very largely for the testing of experimental machines by small makers, which in Germany were usually very badly made. The big firms had, as a rule, their own test grounds.

CHAPTER XII

FIRST YEARS OF FLYING

Most people whose memory goes back to the early years of practical aviation have a vague recollection of much-advertised flying meetings, of air races across kingdoms, continents, and seas, of progressive speed and altitude attainment, and of a growing list of disasters that at one time threatened to call upon private flying absolute suppression by the authorities, and did seriously raise the question whether aviation would ever get beyond the domain of the professional showman.

Some who saw clearly that this phase of noble but apparently wasted effort and courage would be followed by the attainment of comparative safety, and that flying would be recognized as one of the greatest and most serviceable victories of science, had for many years a hard task. It must be admitted they failed wholly to convince the general public, who in England remained curiously indifferent, so that after the first big sensations of the air there was no noticeable increase of enthusiasm: indeed, for a time the crowds attracted by a prospect of seeing flying diminished rather than grew. The fact that there was very little "gate money" to be gained, and that the cost and upkeep of machines was heavy kept away all save enthusiasts, and only manufacturers possessing abundant faith in the future gave of their energy and their capital. At first, indeed, the makers were primarily enthusiasts and savants, and most of them lost heavily. And in the years when flying was dangerous it was, perhaps, well that the number of those who risked their lives was so strictly limited. Had it not been so, there would have been a staggering death-roll followed by prohibition.

Here it may be interesting to recall the world's death-roll of the early years of flying :—

1909	4
1910	29
1911	78
1912	114

It was, however, estimated that in 1911, one of the blackest years, the mileage of flying per fatality was no less than 62,500, a fact that shows justification for the refusal by pilots and manufacturers to give up the struggle and leave aviation to the birds. Each year saw an enormously decreased relative mortality.

This book does not pretend to deal with the history of aeronautics fully, but a review of past progress is essential to a proper understanding of the present position. Very briefly, then, the story of the years 1908–1914 will be resumed in continuation of the subject dealt with in Chapter V.

In 1909 no more than half a dozen Englishmen were flying, but a good deal of public interest was shown in the Aeronautical Exhibition held in the Spring of that year in London, although almost the only practical exhibits were of French origin. In July a very complete aeronautical exhibition was held at Frankfort, and the few British visitors to it were deeply impressed by the thoroughness of the methods with which the Germans approached the development of airships. This was at the time of a remarkable wave of Zeppelin enthusiasm, and of a public subscription of over £300,000 to enable Count von Zeppelin to continue his experiments. At the Frankfort Exhibition the models and plans of airships numbered hundreds. There were several exhibits of anti-aircraft guns ; flights were made on a biplane ; airships were harboured in the grounds ; and there were sections devoted to the natural history of flight and to literature.

While this Exhibition was being held Louis Blériot flew across the English Channel on July 25, and Hubert Latham twice failed to achieve the same feat.

In the autumn an aviation meeting was opened at Doncaster, followed three days later by one at Blackpool. A good deal of flying was seen at these meetings, in spite of bad weather ; and at Blackpool Latham flew in half a gale of wind, a sensational feat at a period when flying was considered impossible save in perfect atmospheric conditions.

Airships took part in the French and the German Army manœuvres in that year ; and at Göttingen University a Chair of Aeronautics was established, the first holder being Herr Prandtl.

The following year saw a number of remarkable developments, big cross-country flights being a feature. Some idea of the great advance in the practice of aerial navigation may be gathered from the fact that whereas up to December 31, 1909, the total number of aeroplane flights of an hour's duration was sixty-four, in 1910 there were no fewer than 350 of over an hour. Of these seventy exceeded two hours, seventeen exceeded three hours, three exceeded four hours, two exceeded five hours, and one exceeded six hours. Thirty were with passengers, seven of the passenger flights exceeding two hours. There were 111 cross-country flights of over an hour's duration, nineteen of these being flights of over two hours, and many of them being flights with passengers. During the year there were more than fifty aviation meetings. Of the international meetings two, those at Bournemouth and Lanark, were held in Great Britain.

In that year excitement was aroused in England by the aerial race from London to Manchester, a prize of £10,000 offered by the *Daily Mail* being won by Louis Paulhan after a close struggle with C. Grahame-White. Although the latter did not finish the course, he had made two bold bids for victory. The machines used by both competitors were Farman biplanes, 50 h.p. Gnome engine, so that there was practical equality of speed capacity.

On the Continent, and more especially in France, flying made steady progress. A big cross-country tour known as the Circuit de l'Est was won by Alfred Leblanc, and a race from Paris to Bordeaux by Bielovucic.

Nearly all the flying at this epoch was on French machines, and where an aeroplane of another nationality was seen it was usually one driven by a French motor. The Wright and Curtiss biplanes, both American, were the principal other types in use, and nothing very original in aeroplane design had so far made its mark either in England or in Germany, although in both countries a few experimenters were at work.

The double crossing of the Channel by C. S. Rolls was effected on a Wright biplane on June 2, and as the author was personally associated with this enterprise, and superintended the signalling on the French coast and arranged for a suitable landing-place in case of need, he begs leave to quote from the account he contributed to *The Times*.

After two weeks of wearisome waiting and watching the machine was sighted on the evening of June 2, having made about three-quarters of the distance before it was caught in the field of vision of binoculars.

"The aeroplane was far to the west about four miles distant, conspicuous against a lovely opalescent sky. This was at 6·58. I waved a white sheet to guide the aviator, and this was apparently seen, as his course was altered towards the east. He passed the coast at 7·5, and was greeted by shouts. He went on inland for a third of a mile, and then turned north-west, apparently to fly down the Channel. He was flying at a height of about 1000 feet, the fragile object at that distance having a peculiar beauty. Some anxiety was caused by the fact that no torpedo-boat was in sight; but slowly the aeroplane shaped a better course, and I now ceased to signal. Rolls evidently intended to surpass Blériot and de Lesseps by making a double journey, and it was a proud moment for myself and for the few English people there. The French spectators were enthusiastic, for they realized that a double crossing of the Channel was a great achievement.

"With our binoculars glued to our eyes we watched the aviator's progress. It was a fascinating task. There was the great expanse of sea and sky. To the right a cluster of warships marked the scene of the sunken submarine and the operations for its salvage, a sad and gloomy reminder of the perils of the sea. A dazzling sun cut a path of burnished brass to the horizon. The heavens were alight with the tenderest hues of green, blue, orange, mauve. There was a curious rainbow effect on cirrus clouds high in the west, and right against it there was the aeroplane speeding to its goal alone in the great expanse. Our hearts trembled at the thought of the vagaries of a motor. There was still no sign of the torpedo-boats that were to attend the flight. His course was clearly too westerly. For half an hour he could be seen with the naked eye, but with binoculars we clearly saw him for fifty-five minutes of his return journey. At length the aeroplane became the merest speck twenty miles away. We believed we saw him descending. Towards the end his course took him nearer the crimsoning glory of the sun, and he vanished finally to the right of Dover Castle. At that moment the twinkling lighthouses of Dover and Calais became visible in the dusk of eve.

"We turned back to Calais, and driving through Barraques were hailed with cheers. The women clapped hands and waved handkerchiefs, a generous tribute to the English, whose long-postponed demonstration of capacity for airmanship is rather a local joke."

Six weeks later Rolls was killed in an accident on his Wright biplane at the Bournemouth aviation meeting.

Early oversea flights were Loraine's passage of the Irish Channel on September 11, 1910; Svendsen's crossing of the Sound; Outochkin's passage of the Gulf of Odessa; Curtiss's flight over Lake Erie; and Sopwith's cross-Channel flight—all in the same year.

The same year saw the aerial conquest of the Alps.

When the organizers of the Milan aviation meeting of September, 1910, announced prizes for a flight across the Alps, they were adversely criticized for offering a temptation to competitors to risk life in order to provide spectators with a thrilling episode. The performance of such a feat, it was pointed out, would not carry the new science a step further. At the same time, when Georges Chavez accomplished the flight at the sacrifice of his life, it was realized, in spite of the outburst of indignation and horror, that he had succeeded in going far towards convincing a still partially sceptical world that humanity was destined to disport itself in the air just as it does on the water, which as a navigable element is by no means completely conquered.

The task set was to fly from Brigue in Switzerland, over the Simplon Pass, across Lake Maggiore to Varese and Milan, a distance of ninety miles. The starting-point was 3280 feet above the sea-level, and the top of the Simplon Pass is 6580 feet high. During the flying the Simplon Pass was closed in order that a motor ambulance could swiftly follow the competitors. The route was marked by sheets of linen and by pillars of smoke rising from fires of pitch. The competitors were Aubrun, Cattaneo, Chavez, and Paillette, on Blériot monoplanes; Weymann, on a Farman biplane; and Wienczier, on an Antoinette monoplane. All the competitors used the Gnome motor. Of these competitors only Chavez dared the feat.

Among mountains the atmosphere is often in a disturbed condition, due to the interruption to currents of air, to swift changes of temperature, and, in the case of the Alps, to snow and ice. Added to this peril was the impossible nature of the country for landing. In the event of the breakdown of the motor, entailing a glide to the ground, it would have been almost a miracle if the most skilful pilot succeeded in avoiding dangerous rocks and forests.

Chavez ascended on Friday, September 23, at 1.30 p.m. He was seen at various points *en route*, and a railway train was stopped on the Italian side in order that the passengers might see the aviator pass. No one knows what Chavez experienced in that memorable flight. From snatches of conversation permitted to him while lying wounded in hospital, it was gathered that over the Simplon Pass he encountered high winds. The aeroplane swerved from side to side, and several times narrowly escaped being dashed to pieces against great rocks. On arrival at the Domodossola valley, Chavez perceived the signals and made preparations to descend at San Diamanti. He was unable to explain the cause of the accident, which, accordingly, is derived from the accounts of eye-witnesses.

On the Italian side of the Alps the aeroplane came into view soon after two o'clock. When over Domodossola it was seen to be descending, and apparently it came straight towards the landing-place, just south of the town. It is believed that the aviator misjudged the distance from the ground, for instead of coming to a nearly horizontal position for landing, his machine struck the ground head foremost at an angle of about 30 degrees, and toppled forward and collapsed. He lay for some days in hospital, and it was hoped that he would recover, but he died on September 27. It is said that on recovering consciousness in hospital he exclaimed: "Heaven be thanked! Oh, ye Alps, ye are conquered!"

There are two theories of the accident. One is that the aviator was benumbed by the cold and could neither see nor feel clearly. Another is that the machine broke. In the latter case it is not impossible that cold may have been partly responsible.

In that year aviators who, it is obvious, risked their lives in a very special sense, won huge fees at flying meetings. To mention two English flyers—Captain B. Dickson was a very big prize-winner, and C. Grahame-White received £6400 at the meeting at Harvard, U.S.A. Heavy expenses were, however, entailed by those who owned aeroplanes.

In 1910 the Gnome motor rapidly took the lead in aeroplane work in spite of its high price, its extravagance in fuel and oil consumption, and its delicacy. Those who criticized it most closely, however, admitted that for a time it aided the progress of flying, being exceptionally light.

The year 1910 was followed by a period of solid progress. Henri Jullerot on a Bristol biplane flew in connection with the Indian Army manœuvres, and T. Sopwith was invited to fly at Windsor before the King. The great European circuit was flown, the winner being Lieutenant Conneau, generally known as "Beaumont." There were flights over the Thames during the University Boat Race. Grahame-White flew down the river through London. An aerial post to Windsor and back was run for a few days. The Paris-Madrid race was flown.

The start of the latter was the occasion of one of the most remarkable disasters in the history of flying. A monoplane designed and flown by a Frenchman named Train charged into the crowd and killed Berteaux, the French War Minister, and severely injured Monis, the Premier.

Other races of that year were the St. Petersburg-Moscow, the Italian Circuit, the Russian Circuit, and the Circuit of Britain. In the last-named Lieutenant Conneau, who had won the European Circuit, proved the victor after an exciting contest, being run closely by Jules Védrines. Both flew Blériot monoplanes driven by Gnome motors. James Valentine, on a Deperdussin monoplane, was third, and S. F. Cody on his own type of machine driven by a Green engine was fourth.

In 1911 the French War Office held a competition to encourage the design of campaigning aeroplanes, and in 1912 the British War Office followed suit, the trials, lasting a month, being held on Salisbury Plain, and being won in all sections by the Cody biplane.

The rise of Hendon as an aviation centre, at about this period, calls for remark. Here was evolved the weekly flying meeting, which ultimately developed into a great success; and it is of particular interest, since nowhere in the world has its like appeared. Races and other aerial contests were in every Saturday's programme, and exhibition flying was also to be seen on Sundays. The crowds in attendance were sometimes very large. Hendon was the starting-point and goal of many important races, such as the Aerial Derby over a course of hundred miles round London; London-Paris; and London-Manchester.

In those early years flying attracted women as well as men, but only to a very limited extent. The first Englishwoman to qualify as a pilot was Mrs. Hewlett, the wife of Mr. Maurice Hewlett, the novelist. Afterwards Mrs. Hewlett established a successful aeroplane factory.

Flying in the French colonies proceeded apace, and many daring flights across the desert, even to Timbuctoo, were made, a system of regular patrols being established. There were extensive tours by squadrons of aeroplanes in Morocco and Tunis. Here and there, in France, experimental aerial posts were tried, in some cases in connection with the ocean services with the object of running a later mail than was possible by the ordinary channels.

With so much flying in aerodromes occasional collisions occurred, in spite of the establishment of the "rule of the road." The first fatal collision occurred at the Brayelle flying ground, near Douai, on June 19, 1912, during fog, when Captain Dubois and Lieutenant Peignan were killed. An earlier, but not fatal, collision occurred at Milan in 1910, when Thomas, flying in a race, tried to pass Captain Dickson, who was practising. Captain Dickson subsequently had to pay £200 damages to Thomas, and £400 damages to the makers of the Antoinette aeroplanes, one of which Thomas was flying at the time.

As to flying accidents in general, a big series of them were due to collapse of machines in the air, the manufacturers in many cases underestimating the degree of strength necessary to bear the strain of high speed, especially in view of the sudden stresses set up by gusts and lulls, and by abrupt manœuvres by the airman. One cause after another was tackled; above all, experience of flying grew, with the result that fewer risks were run.

The amount of flying rapidly increased. During 1913 in France 8,150,000 miles were flown, about two and a half times as much as in the preceding year. The total duration was 133,800 hours, as against 39,000 hours in 1912; 23,600 cross-country flights were made as compared with 9,100. The passengers carried were 47,900 instead of 12,200. The total horse-power of the engines built increased from 89,000 h.p. to 228,863 h.p.

Aeroplanes and airships took part in Army manœuvres of the principal Powers. Much of the best flying was on military Service, and many of the most skilful flyers were quite unknown to the general public, although occasionally some outstanding feat was announced as, for example, when Captain Longcroft, testing a new B.E. at Farnborough, flew this machine to Montrose with the commanding officer as passenger. One landing only was made—at Alnmouth—to replenish with petrol and oil. The journey of about 530 miles took seven hours forty minutes exclusive of the time spent at Alnmouth.

An important feat demonstrating the controllability and the strength of an aeroplane was Adolph Pégoud's vertical circle, known as "looping the loop." This was accomplished on a Blériot monoplane with a few slight structural alterations. Previously, two aviators, at least, had been turned completely over by the wind and had righted their machines; and a Russian officer had flown upside down, and had been punished for "foolhardiness."

There was a good deal of criticism of Pégoud's exhibition, but the hostility of some of the critics was soon replaced by a more generous attitude, when all the leading aviators admitted the value of "looping" as a performance giving confidence. In a few months scarcely one of the leading flyers had not looped the loop, flown upside down, and turned completely over sideways, nor did it appear that there was any especial danger in these feats done with due care and on well-found machines: albeit, it is to be admitted that in one aspect the performance when made for the attraction of "gate money" was to be deprecated.

In 1913 the British Government issued regulations of aerial entry into the United Kingdom, and prohibited all flying over certain military areas. It had previously been ordered that aircraft were not to pass over towns, over crowds assembled at race meetings, and on other occasions.

The year 1914 eclipsed all its predecessors in the quality and the quantity of the flying, and in the preparations for aerial war by all the Powers, to which special reference is made in another chapter.

Gilbert, the French aviator, starting on June 6 flew 2000 miles round France in two days; Lieutenant Geyer flew 805 miles in a day, in Germany; Verrier won the Pommery Cup with a flight from Buc to Genthin, Germany, a distance of 520 miles, in May; Adjudant Quennehen made a 625 miles' flight across country on June 12, without stopping, in thirteen hours forty minutes; the

German aviator, Basser, in four days, spending eighteen hours twelve minutes in the air, flew with a passenger from Berlin to Constantinople, via Buda-Pesth and Bucharest; flights over the Alps were made by Parmelin, on February 11, from Geneva to Aosta over Mont Blanc; by Bider, from Berne to Brigues, by the Jungfrau, on April 23; and by Landini, over the Alpes Apennines, on July 27; a number of flights through Asia Minor by French and Turkish aviators bound for Jerusalem and Cairo were made, the Turkish aviators suffering two double fatal accidents besides minor mishaps.

Three interesting cross-country races, beginning and ending at Hendon, were the occasions of several fine performances. On June 6, the Aerial Derby, a race round outer London of a distance of about ninety-five miles, was won by W. L. Brock, an American pilot, with an average speed of seventy-two miles per hour; the same pilot won the race from London to Manchester and back on June 20, and also the race from London to Paris and back on July 10.

In that year Gustav Hamel, who had for long been the foremost British aviator, and was second only to Roland Garros in skill and experience, was "commanded" to Windsor, and gave a demonstration, including "looping," before their Majesties.

On July 30 Lieutenant Gran flew from Scotland to Norway, an oversea distance of 320 miles.

In the year the Great War broke out several projects for flying across the Atlantic from West to East were under way. Lieutenant J. N. C. Porte, R.N., was nearly ready to make a start on a Curtiss multiple-engine seaplane when he was called back for Service. At the time of his death Gustav Hamel was making rapid preparations for the same feat, in which he was to use a fast and big Martinsyde monoplane.

In 1914 the Concours de Securité in France offered large prizes, and the first trial of contrivances in this competition took place in June, but it was decided that the principal award of £16,000 could not be given. A large proportion of the entries related to stability. The jury awarded £2000 for the Sperry gyroscope, £1200 for the Paul Schmitt biplane, £600 for the Caudron biplane, £400 for the Doutre stabilizer, £400 for the Lelarge carburettor, £300 for the Etève stabilizer, £200 for the Moreau "Auto-Stable," £80 for the Robertin parachute, and £40 for the Philippe and Perron quick-release device.

The development of the high-speed biplane continued, and the former association of the monoplane type with the highest speeds broke down. The reduction of head-resistance in biplanes contributed to this result, and in this direction British makers led the way.

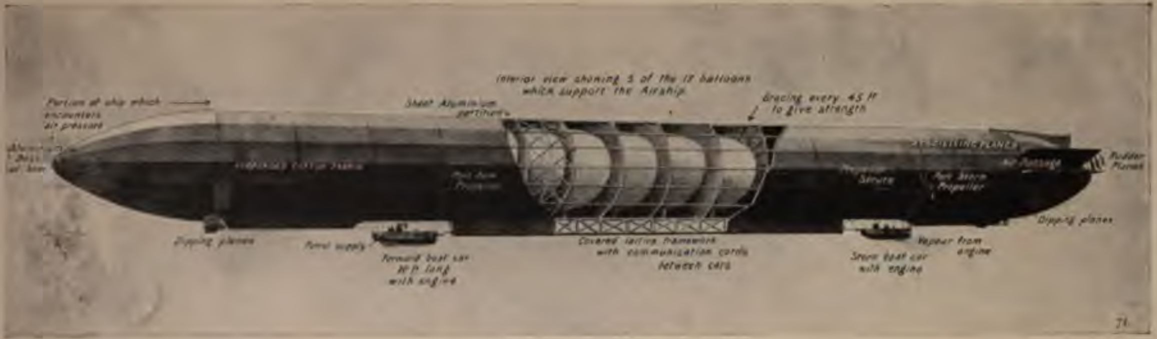
The most important seaplane competition was that at Monaco for the Jacques Schneider trophy, on April 20, 1914. This was won for Great Britain by the Sopwith biplane flown by C. H. Pixton, who covered the course of 150 nautical miles in 2 hours 13⅗ seconds, an average speed of eighty-six miles per hour.

A flight contest from Paris to Pekin had for some months been in contemplation.

The history of flying falls naturally into two parts, the Great War affecting it profoundly, and this chapter deals only with the ante-war period.

Progress in aeroplane capabilities from year to year may be seen at a glance in the following table :—

	Independent speed.	Duration.			Height.	Distance. Non-stop.
Year.	m. per hr.	hr.	m.	sec.	Feet.	Miles.
1908	39	2	20	23½	400	95
1909	49·9	4	17	53	1,640	130
1910	67·5	8	12	0	10,745	365
1911	82·5	11	1	29	13,950	453
1912	108·⅛	13	17	57	17,882	627¾
1913	126·5	13	17	57	19,600	634
1914	126·5	24	12	0	25,756	646


Portion of ship which encounters air pressure
Sheet Aluminium partitions
Interior view showing 5 of the 17 balloons which support the Airship
Bracing every 45 ft to give strength
Port Bow Propeller
Propeller Struts
Port Stern Propeller
Air Passage
Rudder Planes
Dipping planes
Petrol supply
Forward boat car 30 ft long with engine
Covered lattice framework with communication cords between cars
Stern boat car with engine
Vapour from engine
Dipping planes
71

THE ZEPPELIN AIRSHIP

This drawing of the Zeppelin airship in section gives a very clear idea of the construction of the famous dirigible balloon which remained until almost the end of 1909 the only rigid type extant. The object of dividing the gas into numerous compartments was to retain the vessel's efficiency even should one part of it become disabled.

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CHAPTER XIII

MODERN AIRSHIP THEORY

THE years 1913 and 1914 saw a measurable advance in dirigible ballooning. The success of the Zeppelin type, confounding the forecasts of its more uncompromising critics, who had held that there was no future for "gas-bags," had much to do with this. The British Government took an increased interest in airships, when, on January 1, 1914, the control of all lighter-than-air craft passing from the Army to the Navy, the country became pledged to a more ambitious programme than that of any preceding year.

The experience gained by the aid of the small Army airships showed three things, namely, the need for efficient stabilization, the value of swivelling propellers (invented by E. T. Willows), and the possibility of mooring airships to a mast, the nose being held in a swivelling cone. Lessons had also been learned from the failure of the rigid airship, Naval Airship, No. 1 (the "Mayfly"). Further brief reference will be made to these first trials of British airships: and the reader is also referred for further information on the same subject to Chapter IV. But first it is necessary to describe the various main types into which dirigibles are divided.

The lift of an airship depends on the size of the gas-container; roughly, 35,000 cubic feet of gas will lift one ton. The car and its contents constitute the greater part of the load, and if it were carried by a limited part of the envelope, say, the middle, the balloon would buckle. This difficulty is avoided in various ways and, according to the systems used, the ship is classified as rigid, semi-rigid, or non-rigid.

In the non-rigid division, which perhaps because it can take comparatively small and inexpensive forms has always been most numerously represented, the car is usually suspended far below the envelope, and its weight evenly distributed. Most of the early experiments belonged to this division, in which were included Santos-Dumont's airships, the Parseval (German), and several of the small British craft.

A slight modification took the form of placing a girder below the envelope, the car forming part of the girder, as in the British Beta, Gamma, and Eta, and the Clément-Bayard airships.

Semi-rigid airships have a rigid girder, or keel, close up to the envelope, the car being slung immediately below the girder. The Lebaudy (France), the Gross (German), and the Forlanini (Italian) are the best-known examples.

In the rigid division, of which the best-known examples are the Zeppelin, the Schütte-Lanz, the Spiess, and a type adopted by the British Navy, a rigid case contains a series of separate gas balloons.

The principal drawbacks of rigid airships are that they cannot be packed up or deflated quickly. Further, it is necessary to make them large enough to lift about fifteen tons gross weight on account of the heaviness of the structure.

The other two divisions are open to the criticism that the suspension system at best is clumsy, and that there is danger of complete and swift destruction following the bursting of the envelope or from fire. True, in some types, such as the Forlanini and the French "Fleurus," the gas-container is divided into two or three parts. On the other hand, the non-rigid and semi-rigid divisions have the advantage of being capable of swift deflation, for they are provided with a ripping panel. They suffer from the drawback that they become flabby when the ballonnet capacity has been exhausted, and that in that condition they cannot be driven through the air except at the very lowest speed.

All non-rigid and semi-rigid airships are provided with ballonnets, the purpose of which is to maintain the form of the airship in spite of loss of gas by leakage or of the contraction of the gas under increased atmospheric pressure or in decreased temperature. An ordinary spherical balloon loses gas throughout the open neck when the gas expands in warmth or through the reduced atmospheric pressure found with every increase of altitude. On descending again the remaining gas contracts and the balloon becomes flabby. This condition in a dirigible airship would seriously interfere with the car-suspension, and would make it impossible to drive the craft through the air on account of the deformation of its shape.

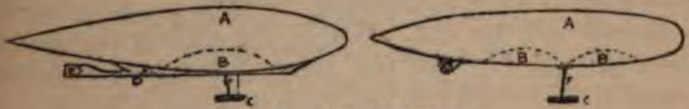


FIG. 41. THE BALLONNET

A. Gas container. B. Ballonnets. C. Car. D. Keel of semi-rigid (Lebaudy). E. Rudder. F. Air-sleeve to ballonnets.

The ballonnet is a small balloon inside the main envelope. It can be inflated with air from a blower driven in all save the smallest craft by an auxiliary motor. The operation of the ballonnet will be readily understood from the example of an airship ascending to a height of 1000 feet. Before the ascent the gas-container is filled, the ballonnet being empty. Throughout the ascent gas is escaping through the automatic valve, its expansion forcing the latter open, and at the height mentioned one-thirtieth of the gas will have so escaped. An airship of 60,000 cublic feet capacity will in these circumstances have lost about 2000 cubic feet of gas.

The moment the airship begins to descend the gas begins to contract, and air is then driven into the ballonnet in order to enlarge it inside the main envelope, taking up more room and compensating for the contraction of the gas. In the case in point, during the descent 2000 cubic feet of air will be pumped into the ballonnet. In a second ascent the air is allowed to escape from the ballonnet as the gas in the main envelope expands.

A simple calculation shows that if the capacity of a ballonnet be one-quarter of the total volume of the airship the safe altitude capability of the craft will be 7500 feet. After descending from that height the ballonnet will be full. But if the airship ascend to 8000 feet, then, at 500 feet above the ground, the ballonnet will be quite full, and on descending lower the gas will further contract, and the vessel will become flabby and incapable of being driven through the air. It can— of course, be used as an ordinary motorless balloon, and, provided the weather be calm and it is possible to get assistance at the landing, no damage need be sustained. These calculations represent the facts broadly: in practice they are subject to slight modifications.

The larger the airship the larger may be the proportional ballonnet capacity, and therefore the greater the height safely attainable.

Some airships have two or even more ballonnets, and by inflating or deflating one more than the other balance may be adjusted.

It is natural that British airship work should have exceptional interest for the reader, who may, moreover, desire to have at hand brief particulars of the several designs that have been tried. The first real airship was one built by A. E. Gaudron for Dr. Barton in 1903. While giving great promise, the design was not persevered with.

In the previous year Colonel Templer, the head of the Army Aeronautical Department, made two envelopes of gold-beater's skin, each of 50,000 cubic feet capacity. But nothing further was done, on account of the inadequacy of the money grants, until Colonel Capper, who had succeeded Colonel Templer, built the first British military airship, using one of the envelopes made by Colonel Templer. This craft was commonly known as the "Nulli Secundus."

The first voyage of this airship took place in September, 1907. In the following month it made a memorable journey over London as far as St. Paul's Cathedral, attaining a nett speed of 18 miles per hour. The late S. F. Cody was pilot, and he brought the ship to rest in the grounds of the Crystal Palace, the wind being adverse. The world's duration record had been broken by this trip, which had lasted 3 hours 25 minutes. It was found necessary to rip open the "Nulli Secundus" where she had landed.

Early in 1909 a small airship that was nicknamed the "Baby" took the air. Its capacity was 21,000 cubic feet, but it was provided with a ballonnet, and was driven by two small motors. At the tail of this craft were vertical and horizontal fins for preserving stability.

The "Gamma" was, meanwhile, being built, and it was a more ambitious effort, the size being 75,000 cubic feet. It was also a more representative British craft than its predecessors, the engine being an 80 h.p. Green. An innovation was its swivelling propellors.

Another of the series, the "Beta" (which in reality was the "Baby" enlarged), driven by a 35 h.p. Green engine, came out in May, 1910, and attained a speed of 28 miles per hour. This vessel achieved fame by a night trip to London and back on the 3rd of June, and in the autumn of the same year it took part in the Army manœuvres, and made a journey lasting 7¾ hours with a crew of three men aboard, accompanied by some carrier pigeons.

Members of Parliament and the public were at this period agitating in favour of a more energetic aeronautical policy, and a Committee of Members of Parliament arranged with Clément-Bayard (Paris) to have a large airship sent over to England with a view to i purchase by the War Office.

The airship performed the journey of about 220 mil in six hours, so that its average speed was about thir eight miles per hour, of which the favouring wind counted for seven or eight. The navigator was Cléme the constructor, and with him were five assistants an passenger representing the Parliamentary Aerial Defe Committee. The appearance of the ship over London a Sunday morning created an immense sensation, although the vessel had been promised for over a ye and was, therefore, expected, the public were not aw that the start had actually been made. Afterwards British Government agreed to accept the airship, but terms which the makers would not accept. The deficie was, however, made up by private generosity. It then found that the envelope was leaking, and a new was necessary, a fact which no doubt led the Governm to regard the price originally asked as excessive. T ship was deflated and was never afterwards used.

This airship had a capacity of 245,000 cubic fe it was 250 feet in length, with a diameter at the larg girth of 44 feet; it was driven by two motors of 125 h. and it was estimated capable of carrying a crew of twe men. The same vessel had been employed with so success in French military manœuvres.

The next airship to cross to London was the Lebau purchased for the nation by subscription organised the *Morning Post*. She was of the semi-rigid type. T voyage was made on October 26, and carrying a crew eight the Lebaudy traversed the distance betw Moisson and Aldershot in 6 hours 5 minutes. The con tions were scarcely so favourable as when the Cléme Bayard crossed the Channel, there being consider fog, and the wind being abeam, so that the performa was a much better one in every way. An unfortu accident marked the termination of the voyage. T airship had safely landed and was being hauled into the shed when the top of the envelope caught in the roof and was ripped open. This was in no sense a fault of the vessel, but was due to the fact that the shed placed at its disposal was far too small. The British representative on board on this historic voyage was Major Sir Alexander Bannerman, who had just been appointed to the command of the aeronautical division of the army. On May 6, 1911, after a trial trip, this airship was almost completely wrecked in a bad landing. The Lebaudy airship had a cubic capacity of 350,000 feet; she was 337 feet long, and was driven by two motors of 135 h.p. The semi-rigid type to which she belonged differed from the non-rigid like the Clément-Bayard, in having a metal frame under the gas-envelope, which is thus preserved in better shape when partially deflated by leakage or other causes. This frame also enables the car to be suspended in a manner that does not distort the gas-envelope.

Early in 1911 the "Delta" was put into commission, and although she was the fastest airship in existence, except the Zeppelins, and attained a speed of forty miles per hour, she was continually under repair or being altered.

The next of the series was the "Eta," which made history on August 20, 1913, by actually towing another airship, which had been disabled, fifteen miles home to Farnborough.

In a number of important technical details the British were doing excellent work. As already mentioned, the mooring of airships to a transportable mast was initiated in this country, the mast having at its top a swivelling cone into which the nose of the airship fitted.

Privately, practically nothing was done in England in airship work, except by E. T. Willows, who made a number of successful voyages in a small vessel embodying some very satisfactory features, including a rigid boom between the envelope and the car giving rigidity and strength to the structure and simplifying the suspension problem.

France, meanwhile, was engrossed with aeroplanes rather than with airships, just as Germany preferred the latter to the former, and from 1913 the success of Germany's airships was so marked that it attracted the attention of the whole world. A regular passenger service was run, and details of the year's workings are here recalled.

The statistics deal solely with the "Viktoria Luise," "Hansa," and "Sachsen." The "Hansa" made 210 trips on 148 days, covering 15,600 miles, and carried 4,086 persons, 2,615 being members of the crew (i.e. the same people over and over again), and 1,471 passengers. The "Sachsen," which made its first trip in May of that year, made 206 trips on 127 days, covering 13,700 miles, and the "Viktoria Luise" made over 400 tours. Figures are obtainable only for the first 160 voyages, when a distance of 10,000 miles was covered and 3,439 persons conveyed. All three airships were used extensively for military tests, and a certain mileage would have to be added for this. The three passenger vessels together conveyed 12,382 persons, and covered 37,500 miles.

The story of the airship cannot be given in perfect chronological order, and it is now necessary to go back to the Wellman enterprises, the object of the first being to travel by air to the North Pole. This was to be attempted in a dirigible balloon starting from Dane's Island. Abortive attempts were made in 1907 and 1909.

The gas-container of the Wellman airship had a capacity of 258,500 cubic feet. It was 184 feet in length and 52 feet in diameter. The motive power was obtained from a 70 to 80 h.p. Lorraine-Dietrich engine. To maintain the gas-envelope in a fully inflated condition, a separate 4 h.p. motor was carried to compress air and conduct it to an internal ballonnet placed in the lower part of the main balloon. The car had a strong frame of steel tubing, and a completely enclosed central section which comprised the engine-room and living-room. For maintenance of vertical equilibrium a guide-rope weighing 1800 lbs. was constructed to act equally well upon water and upon ice. The lower end had four steel cylinders about 10 feet apart attached to the steel cable, with wooden runners outside. The cylinders were so arranged that they would float in water.

Wellman abandoned his project in 1909 after the misfortune of the storm which wrecked his balloon-shed, followed by the breaking of the provision-packed guide-rope, synchronizing as these incidents did with the discovery by Peary of the North Pole.

The Wellman airship " America " started in October, 1910, on an attempt to cross the Atlantic from Atlantic City for Europe. The balloon was essentially the same as that in which Wellman made his attempt at an aerial voyage to the North Pole. It was the largest non-rigid airship in existence, having a cubic capacity of about 350,000 feet, and its nett lifting capacity was about six tons. The principal mechanical contrivance introduced for the attempt was the remarkable equilibrator, or guide-rope. This was 180 feet in length, and weighed about two tons. It was attached to the car by a steel cable 320 feet in length which ran through the entire length of the equilibrator. About 100 feet of the latter was composed of a series of cylindrical reservoirs fitted to each other by a kind of ball and socket joint, so that they looked like a tremendous chain of which each link was over a yard long. These reservoirs contained spare fuel, and each could be raised independently into the car so that its contents could be used for consumption in the motors. The remainder of the guide-rope was made up of blocks of wood reinforced by steel bands and jointed to each other in the same manner as the petrol tanks. The purpose of this equilibrator was the same as that of any other sea-floater or trail-rope, namely, to preserve the altitude of the airship without the loss of ballast or of gas. The slightest ascensive movement took a portion of the chain off the water, checking the rise by its weight ; and whenever the airship was brought to a lower altitude by reduced temperature or the deposit of rain, part of its burden was borne by the water. Sea-floaters had been tried with success on various occasions, but only in calm weather, and Wellman, as the author of this book pointed out at the time he was making his arrangements, depended on a fairly strong breeze to help him across the Atlantic. There was, therefore, considerable danger that the use of the ballast-trailer would lead to trouble by acting as a drag on the airship's progress, causing her to plunge down towards the waves. This is precisely what happened, and the result was that the airship was very nearly wrecked before her crew abandoned her and took to their lifeboat. Wellman admitted in his account of the voyage that the ballast-trailer was a " fatal mistake."

With every possible appliance in the way of signalling apparatus, wireless telegraphic installation, and instruments, the airship started on October 16, 1910, with Walter Wellman in command, assisted by Vaniman, his engineer, a wireless operator, an assistant engineer, and a mechanic. For a considerable distance their course was north-easterly, and they were not far from land. From time to time wireless messages were received telling the world of the progress made, but from noon of the 17th to the afternoon of the 19th there was no news. Then came a wireless message from the steamer *Trent* as follows :—

" At 5 a.m. sighted Wellman airship 'America' in distress. She signalled by Morse code that she required assistance and help. After three hours' manœuvring and fresh winds blowing got Wellman with entire crew and cat. They were hauled safely on board. All are well. 'America' abandoned in latitude 35·43 north, longitude 68·18 west."

So ended an enterprise doomed from the first to failure, but none the less interesting and certainly all the more intrepid.

It appeared, from the account of the voyagers, that the ballast-trailer proved unmanageable, and there was a constant tendency, even in a light wind, for it to drag the airship down. Further, the vibration transmitted from the waves through it to the car very nearly wrecked the machinery. After a journey of about 300 miles the course of the airship could no longer be directed, and she drifted towards the south. The rescue occupied several hours, and it was only accomplished at great risk. Indeed, the airship's lifeboat was holed by the equilibrator, and two of the crew received injuries. The reference to the cat in the telegram is to a black cat taken on board for luck. Certainly the rescue of the entire crew from so dangerous a position must be counted fortunate, but whether it was due to the cat or not cannot certainly be stated.

On July 2, 1912, the "Akron," an airship built by Melvin Vaniman (formerly Wellman's engineer), while on a trial trip in preparation for a journey across the Atlantic, exploded at a high altitude near Atlantic City. Vaniman and his four assistants were killed. It is supposed that a spark from the engine ignited the gas.

At the beginning of the Great War the British Government in addition to the airships mentioned above, possessed a dirigible of the type Astra-Törres; and there were a number of Parsevals and Forlanini on order. A second large rigid airship was put under construction at Barrow. The latter vessel was to be 540 feet long, and have a capacity of 850,000 cubic feet, enabling her to carry fuel and stores for a 34-hour journey, with a crew of fifteen. She was to carry three guns on a suspended platform, and two on top of the hull, while the designed speed was fifty-five miles per hour, with engines of 1,000 h.p.

In the Forlanini type there is a double envelope with an air-space between. The gas-container is divided by eleven transverse partitions. Longitudinal balance is maintained by moving water from one ballast tank to another. The dimensions, etc., are length, 240 feet; capacity, 345,000 cubic feet (ballonnets, 18,000 cubic feet); gross weight, 42,000 lbs.; lifting power, 61,500 lbs.; useful lift, 19,000 lbs.; engine, two motors each of 85 h.p.; petrol capacity for twenty-four hours; speed about forty-six miles per hour. In this airship the car, which is completely enclosed and has windows in front, forms part of the actual keel.

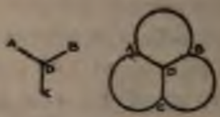


FIG. 42. ASTRA-TÖRRES AIRSHIP
Cross section.

The Astra-Törres airship has its gas-compartment divided by three longitudinal sections, and in end aspect appears like a shamrock leaf. Where each of these lobes joins the other two a steel cable extends throughout the length from bow to stern, there being three of these cables, two above, port and starboard, and one centrally along the keel. Another steel cable extends along the centre from bow to stern, and each of the outer cables is connected to the central one by a great number of short ropes only some six inches apart. A cross section of the hull would appear like the letter Y. A, B, C being the outer cables, D the centre cable, and the lines of the letter itself the ropes. With the lobes the appearance is as shown.

The car is suspended by steel cables taken through gas-tight channels to the cables A and B, and the weight of the car is uniformly borne by the interior skeleton.

An interesting type of airship evolved during the war was the small British patrolling type, a most ingenious craft, consisting of the complete fuselage and engine and landing carriage of an aeroplane surmounted by a cigar-shaped non-rigid balloon of about 60,000 cubic feet capacity. This craft was used principally for coast patrol and submarine hunting. Capable of a speed of about fifty miles per hour it was, of course, limited as to duration and altitude.

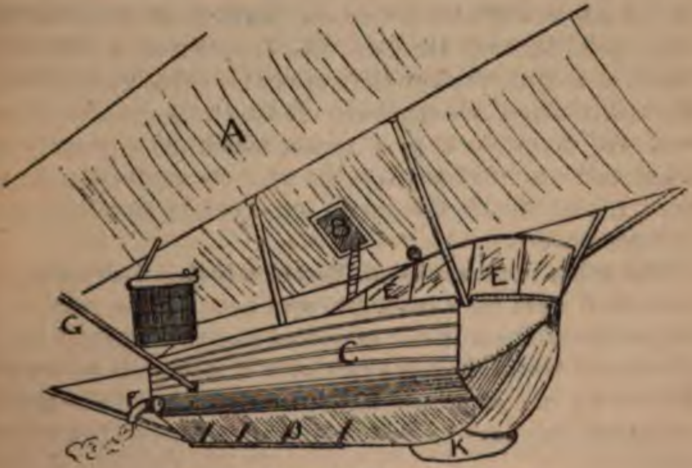


FIG. 43. ZEPPELIN'S FORWARD CAR

A. Rigid envelope. B. Window. C. Car. E. Wind shield. F. Exhaust pipe. G. A propeller shaft. H. Radiator. J. Handrail, for landing. K. Shock absorber.

The Zeppelin airship has its gas-balloons, eighteen to twenty-three in number, contained in a lattice-work cylinder with from sixteen to twenty sides in cross section, built of aluminium tube. Each of the gas-bags has an ordinary deflating valve, and an automatic safety valve. The capacity of the later vessels varies from 900,000 to 1,200,000 cubic feet, and the dimensions are from 480 to

560 feet in length, diameter 40 to 50 feet. The cars are built close to the hull and are usually two in number; they have double bottoms and rubber shock-absorbers, and are fitted for descents both on water and on land.

The Zeppelin depends not solely upon the lift of its hydrogen for ascent; it has two horizontal rudders which can be tilted upwards, giving a certain lift when the ship is propelled forwards. The long under-surface of the airship itself would also act as an elevator when driven at high speed through the air. The Zeppelin airship has no need for ballonnets, but the automatic valve provides for the escape of gas on expansion. Between the gas-chambers and the framework is a space which in war-craft is filled with an inert gas serving as some protection from fire; it also shields the gas to some extent from changes of temperature.

One other important consideration is that water can be recovered from the consumption of petrol. Theoretically, the weight of the water so produced is slightly greater than the petrol used; but in practice it is not quite so great. The water, of course, can be used as ballast and employed to lighten the ship's load when from any cause its buoyancy decreases.

CHAPTER XIV

FIRST USE OF AIRCRAFT IN WAR

WRITING to his friend, Sir Horace Mann, in 1785, Horace Walpole gave expression to an unconscious prophecy: "I expect they will soon have an air fight in the clouds." Nine years afterwards a French balloon saw service at the battle of Fleurus, and there has not been an important war since then without aircraft. But not until the Great War of 1914 was the prophecy literally fulfilled.

No more than a bare summary can here be given of the first occasions when balloons were used in war; but this summary will perhaps surprise many who may have imagined that the balloons which ascended from Paris during the siege of 1870 were the first, and that nothing much was done afterwards until 1914.

1794. June 2. Ascent by French balloon during the battle of Maubeuge.
June 26. Ascent during the battle of Fleurus.

1796. Balloons with Jourdan's army made ascents in front of Andernach and Ehrenbreitstein, and were captured by Duke Karl's Austrian army at Würzburg.

1798. The first company of French Aérostiers ordered to Egypt. Destruction of balloon materials in the battle of the Nile.

1799. The French Aérostiers sent up several Montgolfières from forts in Cairo.

1849. Austrian bombardment of Venice with balloon torpedoes. At the suggestion of Uchatius, an artillery officer, the range of the besieging batteries being insufficient to bombard the town, Montgolfières made of paper were used. Each could lift 70 lbs., and each carried bombs weighing 30 lbs. for thirty-three minutes. Position was chosen on the windward side. A trial balloon was liberated for a course laid out on a chart. Then a balloon with bomb was liberated after timing the fuse. By this means bombs fell in the town (one in the market-place) with great moral effect.

1859. Lieutenant Godard (French) ascended in Montgolfières at Milan and Castiglione. In the latter ascent he detected some important movements of the enemy.

1861. Lowe (U.S.A. Civil War) made a free ascent after a defeat near Manasses, and discovered position of victorious Confederates, showing the falseness of a report that their army was making a general forward movement.

1862. A balloon division reconnoitred for MacClellan's army (U.S.A. Civil War). Ascents and descents under heavy artillery fire in various engagements.

May 4. A balloon showed that Confederate General Magruder had left his position during the night.

May 24. General Stoneman ascended, and, from the balloon, directed artillery fire (the first instance of the kind).

May 29. Important work by balloons at Chikahoming, and later at Fair Oaks and Richmond, where a balloon was attached to a locomotive and moved from place to place.

August 16. Discovery by a balloon of the fleet under Wilkes in the James River.

1869. During siege of the Duke v. Aidzu's fort at Wakamatzu by the Japanese Imperial troops, besieged sent up a kite with a man who dropped explosives.

1870. Siege of Paris. Between September 23, 1870, and January 28, 1871, sixty-five balloons, carrying 164 persons, 381 carrier-pigeons, 5 dogs, and 10,675 kilogrammes of post material, got out of Paris.

Two German balloon detachments, with balloons purchased from England, attached to the army before Strassburg. One ascent was made on September 24.

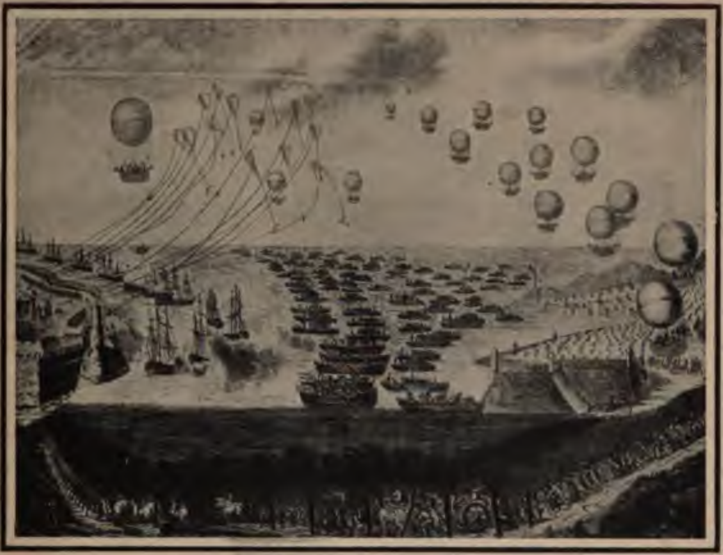
1876. Small captive balloons were used in war by Japan.

1884. A French balloon section of four balloons saw service in Tonkin, and were used in the battle of Hong-Hoa.

1885. Major Elsdale in command of balloons accompanied Sir C. Warren's expedition to Bechuanaland. Many ascents were made.

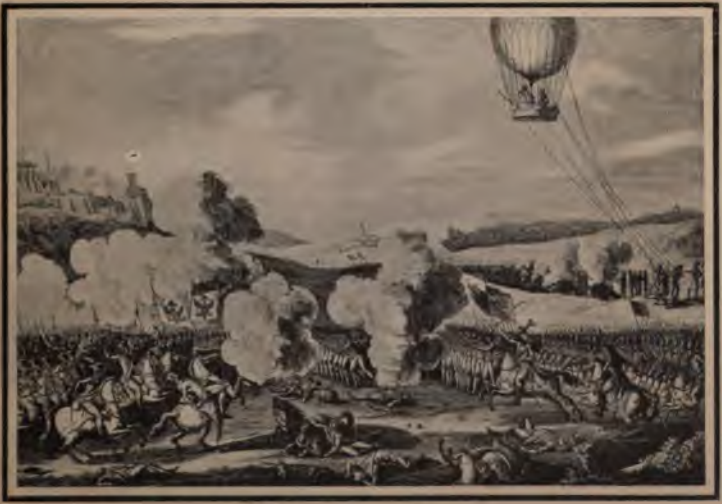
A balloon detachment was sent to the Soudan under Major Templer and Lieutenant Mackenzie. The hydrogen was sent from Chatham compressed in cylinders. Ascents were made during the march to Tamai. A German military critic said of this work: "Practical application of ballooning left nothing to be desired."

1888. Italian army used balloons successfully in Abyssinian operations.



PROJECTS FOR THE INVASION OF BRITAIN

A French engraving during the Napoleonic wars illustrating an imaginary conquest of England by air, water, and a Channel tunnel.



THE BATTLE OF FLEURUS

A war balloon used by the victorious French on the 26th June, 1794. It performed valuable service

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ASTOR, LENOX
TILDEN FOUNDATIONS

1898. United States war with Spain. Ascents at Santiago. Useful observations.

July 1. Ascents at El Poso.

1900. Balloon Section I., under Captain Heath, was sent to Natal. On the night of January 18 attempted to discover Boer position on the Tugela with the help of searchlights. Balloons were used during the battles of Vaalkrantz, Spion Kop, and Springfontein. On February 10 a balloon was shot down by Boer artillery.

Balloon Section II., under Captain Jones and Lieutenants Grubb and Earle, was ordered to join Methuen's army. Ascents were made before Magersfontein. Balloons accompanied Lord Roberts to Paardeburg, and helped to locate Cronje, and directed artillery fire during five days' observations. Balloons were constantly under fire.

Balloon Section III., under Lieutenant Blakeney. Balloon used at Fourteen Streams.

1900. Chinese balloons and stores fell into the hands of the Russians at the capture of Tientsin.

1904. Japan *v.* Russia. A balloon division at Port Arthur. Here a kite-balloon was used for the first time in war.

A Russian naval balloon division sent to Vladivostock, and a balloon company to Manchuria. Ascents were made at the battle of Liaoyan. A Russian balloon was under fire at the battle of Mukden. Very useful work was done.

1909. Spanish kite-balloon used in operations against the Moors.

1911. In fighting on Mexican frontier aeroplanes were used.

Spain, in Morocco campaign.

1912. { Balkans War. Bulgaria, Greece, Roumania, Servia, and
1913. { Turkey.

Italy used aeroplanes, airships, and kite-balloons in Tripoli campaign.

The following is a list of the dates when the various Powers adopted ballooning for military use :—

1783. France.
1807. Denmark.
1812. Russia.
1849. Austria.
1861. United States.
1862. Great Britain.
1869. Japan.
1870. Germany.
1884. Spain.
1885. Italy.
1886. Belgium.
,, China.
,, Holland.
1888. Servia.
1893. Roumania.
1897. Switzerland.
,, Sweden.
1902. Morocco.

It must not be assumed, however, that all these Powers possess effective aeronautical sections to-day or that their progress is proportionate to their early adoption of aeronautics.

It may be interesting to record here the circumstances under which the first military aeronautical division was formed, and the first action in which it took part. Says Wise with regard to the French Balloon Division :—

"It was formed with the utmost secrecy, so that the Powers opposed to the French could not avail themselves of its advantages, until the first projectors had already used it in such an effective manner as to greatly paralyze them. In order to have it at once facile and useful, it was necessary to reduce it to systematic practice. The management of the Aeronautical School was committed to the most eminent philosophers of Paris. Guyton de Morveau, the celebrated French chemist, and Colonel Coutelle superintended its operations. Fifty young military students were admitted to this school for training. A balloon of 32 feet in diameter was constructed, of the most durable materials, as a practising machine for these pupils. Although the original plan of generating hydrogen gas was by decomposing water with the aid of oil of vitriol, and iron filings and borings, De Morveau introduced another method in this case. For this purpose, six iron cylinders were fixed by masonry in a simple kind of furnace, each of their ends projecting, and covered with an iron lid. Two sets of metal tubes were also inserted into these lids, one for conveying in the water, and the other for carrying off the gas which was formed from the water. The cylinders being charged with iron turnings, and brought to a red heat, the humidity of the water was instantly converted into steam, whose expanded particles were soon decomposed by the oxygen uniting with the red-hot iron, forming an oxide of iron, while the hydrogen was thus freed and forced out by its own pressure from the other tube. From thence it passed through a washer of lime-water, to make it deposit the carbonic acid gas that might adhere to it, and it was then perfectly pure and ready for the balloon. By this method they procured, at a very moderate expense, a quantity of gas sufficient to inflate a balloon 32 feet in diameter, with a capacity of 17,000 cubic feet, in the space of four hours. The practising balloon was kept constantly full, so as to be at all times ready for exercise, and when not in use it was fastened to the terrace of the lodge, in the open air. Whenever the weather was fair, the Colonel of the corps and a pupil seated themselves in the car, and the machine was allowed to rise 500 or 600 feet, arranged by cord and windlass. This primary movement became an object of great interest, from the advantages it seemed to possess. Paris, being at this time the great military focus of the world, could by these means view with Argus eyes the movements around the great metropolis. Telegraphic communication was greatly facilitated to the governmental centre by the aeronautic observers. A balloon was also constructed for this school, which, when filled with hydrogen, required the strength of twenty men to keep it to the earth. It could, after the lapse of two months, without being in the meantime replenished with gas, raise into the air two men, with necessary ballast and all the instruments of observation. Colonel Coutelle constructed balloons specially appropriated to the different divisions of the French Army, viz. the 'Entreprenant' for the army of the north, the 'Céleste' for that of the Sambre and Meuse, the 'Hercule' for the army of the Rhine and Moselle, and the 'Intrépide' for the memorable army of Egypt."

The first military balloon division included a drummer-boy! The uniform of this branch of the service consisted of a blue coat with black collar and facings and red braid. The buttons bore the word "Aérostiers." These soldier-aeronauts were armed with swords and pistols. Within two months of their formation they were employed in the battle against the Austrians at Maubeuge in the first and one of the most dashing exploits in military ballooning.

Because they were artisans, these soldier-aeronauts were regarded with contempt by the swashbuckling, fire-eating warriors that in those days made battles, with the result that their commander, Coutelle, begged for an opportunity to distinguish themselves. This was given to them. An ascent was made under fire, and, one way and another, a sub-lieutenant was killed and two of the men were badly wounded. But the work done was invaluable. Never had there been such accurate reports of an enemy's movements. The Austrians objected strongly, and they had a superstitious dread of the aerial monster. General Jourdan, himself, made several ascents. In the same month ascents were made near Charleroi, and also at the battle of Fleurus, describing which Carlyle wrote :—

"Or see, over Fleurus in the Netherlands, where General Jourdan, having now swept the soil of Liberty, and advanced thus far, is just about to fight, and sweep or be swept, hangs there not in the Heaven's vault, some Prodigy, seen by Austrian eyes and spy-glasses : in the similitude of an enormous Wind-bag, with netting and enormous Saucer depending from it ? A Jove's Balance, O ye Austrian spy-glasses ? One saucer-scale of a Jove's Balance ; *your* poor Austrian scale having kicked itself quite aloft, out of sight ? By Heaven, answer the spy-glasses, it is a Montgolfier, a Balloon, and they are making signals ! Austrian cannon-battery barks at this Montgolfier ; harmless as dog at the Moon : the Montgolfier makes its signals ; detects what Austrian ambuscade there may be, and descends at its own ease. What will not these devils incarnate contrive ?"

On entering Moscow, the French Army found in the camp of Voronzoff a large Russian balloon. They made attempts to raise it, but without success.

For observation purposes the captive spherical balloon has been in use since 1794, and in the latter half of the nineteenth century the British Army, on account of the numerous lesser wars that occupied its attention, had gained more military aeronautical experience than other armies. Unfortunately, the captive spherical balloon cannot be used except in calm weather or when very light winds are blowing. Hence arose the need for the man-lifting kite: and here Great Britain again led the way, the Cody Service kite being the best in the world.

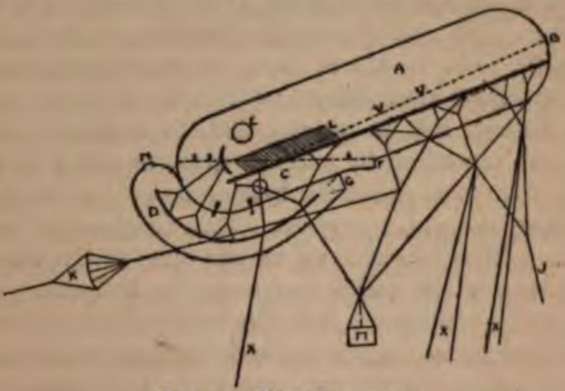


FIG. 44. KITE BALLOON

A. Gas container. B. Valve. C. Ballonnet. D. Air-rudder. E. Deflating sleeve. F. Air inlet to ballonnet. G. Inlet to air-rudder. H. Car. J. Cable. K. One of the tail parachutes. L. Sails. M. Air outlet. S.S.S. Wall of ballonnet. V.V.V. Automatic valve-line. X. Ropes for handling on ground. Arrows in air-rudder indicate small apertures allowing air to pass out of the ballonnet during the expansion of the gas.

Possessing a large number of balloons made of gold-beater's skin, which although very expensive was superior to any fabric, and a very efficient man-lifting kite, Great Britain was content, and when Major von Parseval and Captain von Sigsfeld in 1895 invented the kite-balloon the British was the only army of a First-Class Power that did not almost immediately adopt it. It is described in this chapter because it is a purely military aircraft of no specific aeronautical interest.

The kite-balloon can be used in a calm, or in any wind up to forty miles per hour. It is a sausage-shaped balloon held by a wire cable attached under the forward end, the suspension of the balloon being so contrived that it is inclined at an upward angle of about 40 degrees towards the wind. The valve is in the middle, at the forward extremity. The basket is slung by running rigging to a band extending along the equator of the balloon.

The balloon has an air-chamber, or ballonnet, at the lower end, separated by a diaphragm extending from the middle of the rear end of the balloon to a point about halfway along the under surface. This air-chamber has an aperture at the forward end always open to the wind : it can be seen in the under surface of the balloon at about the middle. Air flows into the ballonnet to an extent determined by its capacity, which varies according to the volume of the gas in the gas-container. By this means the shape of the balloon is preserved, even when the quantity of gas is diminished, for in that case the air in the ballonnet presses the diaphragm out so that it takes up some of the gas-chamber capacity.

The ballonnet serves a further purpose in that it provides an automatic control of the valve : a line extends from the valve to the diaphragm, and when the gas expands the diaphragm is pressed back, the cord becomes tight, and, at a given pressure, opens the valve, thus permitting the escape of just so much gas as will relieve the interior pressure, when the valve automatically closes again.

Under the rear end of the balloon is an air-rudder, which also offers an open neck to the wind admitting air, but contrived as a non-return valve so that the air cannot return through this opening. The circulation of the air is maintained with the aid of a small exit at the end of the air-rudder, and by means of two small apertures in the division between the ballonnet and the air-rudder, the latter openings allowing air to pass out of the ballonnet during the expansion of the gas. The rudder acts as a steadying influence, preventing the balloon from swinging violently to and fro.

The valve can be manipulated by means of a cord carried to the basket. Emergency deflation is provided for by a ripping panel.

Further to steady the balloon a parachute-tail is attached. This is a cord carrying a variable number (from 1 to 7) of small parachutes opening against the wind and acting more or less powerfully according to the strength of the wind. The full number of parachutes are kept on for strong winds: in a calm the tail may be discarded, as the parachutes then serve no useful purpose.

The lift of the kite-balloon is increased by a narrow sail on both sides of the balloon extending for about a quarter of its length near the rear end. These sails extend at right angles from the balloon to a width of about 36 inches, and they counteract the downward pull of the parachute tail.

For naval purposes, Great Britain until 1909 did little beyond experiment with kites. In 1890, France established naval balloon depots in Toulon and Brest. Russia, in 1894, conducted experiments in the utility of observations of the ocean bed from a height; attempts were made to locate the sunken warship Russalka, but were unsuccessful. Certain data with regard to the observation of the sea-bed were, however, established. Aerial craft of all kinds prove useful in observing sunken craft.

In 1899, the Hague Conference passed a vote prohibiting aircraft from discharging projectiles or explosives, but leaving them free to be used for observations. This was passed at the second Hague Conference, but Germany, France, and Italy withheld their assent.

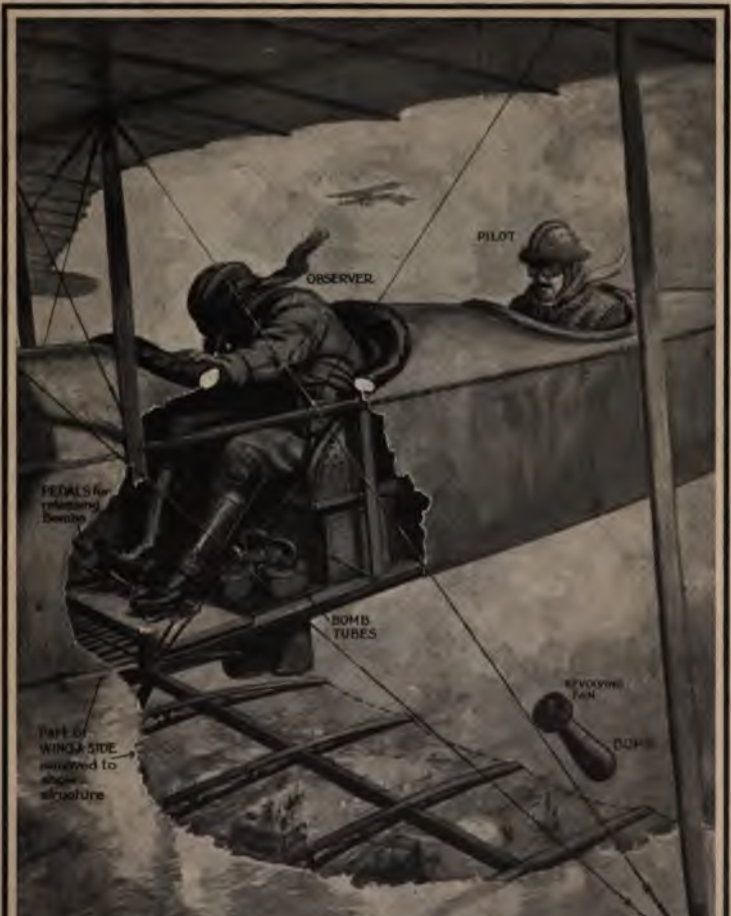
Protection had already been given to the navigators of balloons under the Hague Conference when used for message-carrying and keeping up communications. This was due to French initiative, and as the result of experiences in 1870, when some French aeronauts were subjected to harsh treatment by their captors.

The siege of Paris brought the balloon into service under most romantic conditions. No fewer than sixty-five balloons left the besieged city, some to fall into the enemy's hands, others to convey important personages from isolated Paris, others to convey letters, and two to be lost at sea. In the same war the Germans formed two balloon detachments under the direction of the English aeronaut Coxwell, but very little service to the invading force was done.

The balloon service in besieged Paris was under the direction of the Brothers Eugène and Julius Godard and of Yon and Dartois. The Godards had charge of the Orleans railway station depot, the others had the northern station. Godard's balloons were coloured red and yellow or blue and yellow, the balloons of Yon and Dartois were white.

On one occasion Tissandier threw down 10,000 copies of a proclamation addressed to the Germans. It demanded peace, but asserted that nevertheless France was prepared to fight to the end. On October 7, Gambetta left Paris in the balloon "Armand Barbes," with the object of organizing a fresh army to march to the relief of the city. The balloon came perilously near the earth close to the German outposts, and shots were fired, one striking Gambetta in the hand. By throwing ballast the balloonists escaped.

The Pigeon Post was organized by the Paris Pigeon Fanciers' Society. The despatches, of course, had to be


PILOT
OBSERVER
PEDALS for releasing Bombs
BOMB TUBES
REVOLVING FAN
BOMB
Part of WING & SIDE removed to show structure

An Aeroplane Raid

Bomb-droppers at work.

"At any time in my flight I could have dropped a bomb and been sure to hit what I aimed at. I believe that it would have been next to impossible to hit me. If I had intended attack I would have ascended to a height of 2000 feet, whence I could have produced the same effect."

During his return flight Hamilton startled an American sentry who was standing on the bank of the Rio Grande, with his back to the airman. The latter glided down towards him from 1000 feet. The moment he heard the machine the sentry turned and brought his rifle up. Then, as the aeroplane rushed directly towards him he gave a yell and plunged into the river. Hamilton altered his course and flew onward. The sentry, when last seen, was standing waist deep in the river, shaking his fist and evidently exercising his vocabulary.

In the same year aviators operated with the Spanish forces in Morocco, and did some very useful work with great courage and at some loss.

The terrible Wars in the Balkans which began in 1912 were the occasion of considerable aeronautical activity, and although none of the Powers engaged possessed a well-organized Air Service, very important work was done. In many cases French, British, and German aviators and machines were employed. These campaigns proved a severe test of aircraft, for the absence of good roads and the mountainous character of much of the country almost prohibited transport of aircraft by road.

The spectacle of the battle of Lule Burgas seen by an airman is described by Snowdon Hedley in the *Daily Chronicle* in the following terms:—

"We struck the railroad a little west of Mandra station, and then moved along it eastward. Up at our height, with the roar of a 100 h.p. Argus engine throbbing and whirring in our ears, sounds from the battlefield were inaudible till we were practically over it, and our first idea of the great fight now closing was given us by the sight of a low-hanging silvery haze, which was the smoke of battle to the north-east of the line.

"As we came over Lule Burgas station we began to get some idea of the way things were going. From the station the road runs northward to Lule Burgas village and is skirted on the east by a low line of hills, the last of the line along which the thirty miles of battle had been raging. At the foot the Turkish infantry still maintained their position, with the Bulgarians facing them on the west side of the road. When we came over them only a few hundred yards separated the opposing forces, and as we circled the station the Bulgarians left their last cover and surged across towards the enemy.

"It must not be imagined that I divined all this with my naked eyes—I a mile and three-quarters nearly vertically above this living map of war. What I saw was this. Through rifts and lightenings in that silvery haze were certain dark masses made up of infinitesimal specks. Certain specks from one mass would disentangle themselves and rush towards another mass; more and more they came. They were our infantry falling on the Turks. Nothing but their dispositions could tell me which was which. It was like looking through a microscope at the movements of life invisible to the naked eye.

"Of the tactics I could discern very little, and my general conception of the whole was gathered from the information shouted through the speaking tube at intervals by Popkrissteff, when he could drag himself from the contemplation with his glasses of the scene below and around. His excitement was intense all the time, but intensest of all when he realized that before the advance of his countrymen the hated Turk was giving ground, drawing back across the lower slopes of the hillside."

Bennett Burleigh, the War Correspondent, related on December 2, 1912, the following incident :—

"A couple of Bulgarian aviators late yesterday afternoon had a thrilling experience in a biplane over Adrianople. They told me they flew purposely at an elevation of only about 1700 yards. They could see the city and the movements of the Turks in the streets and forts quite clearly. The Bulgarian batteries were heavily shelling the enemy. The Turks proceeded to fire upon the aviators. All the shells burst at least 350 to 450 yards below the machine. For half an hour the aviators flew about, taking note of everything. They saw that the Selim Mosque was intact, and that most of the other important buildings were undamaged.

"A startling surprise, however, was in store for them. The Turks had sunk a gun in a pit, and fired as they passed overhead—a bow drawn at a venture, so to speak. My two Bulgarian friends heard a loud, hurtling roar of shell ascending direct towards them, and their ears were filled with its screech, which drowned the noise of the engine and the humming wires, as the missile passed upward. It burst, but they had by that time gone a long distance forward, and none of the fragments came near them. They returned, landing safely at Mustafa Pasha.

"I witnessed this incident. A lieutenant aeronaut, before taking his seat in his machine, hastily stuffed his magazine pistol into his coat pocket. Asked why he did so, he replied, in English, 'A Bulgarian cannot be taken alive by a Turk. In case of accident I must sell my life dearly, and always be prepared to do my duty.'"

A few days later he wrote :—

"Aeroplanes have been busy every day flying about and over Adrianople, marking down all the Turkish positions. Biplanes are mostly used. The staff declares that they have admirably succeeded in their task."

In the operations against the "White Wolf" bandits in Shensi, in 1914, the Chinese employed aeroplane scouts with great success.

In the same year the Mexican Federals captured an airman named Didier Masser, and executed him as a spy, thus raising the question of the status of the air-scout. The incident caused discussion at the time, but the point was settled in the Great War, in the course of which numerous airmen were captured by both sides and treated as ordinary prisoners of war.

CHAPTER XV

THE GREAT WAR: FIRST STAGES

WHEN the Great War broke out preparations were being made for a seaplane race round Britain, for the Gordon-Bennett, 1914, and for other big tests of men and aeroplanes. It was believed that Great Britain had a good chance to win the Gordon-Bennett with an all-British machine, the reason being that for the first time in its annals the race was to be won not solely by high speed, but that all machines were to be proved capable of maintaining flight at a certain minimum; and Great Britain had developed a type of small fast biplane having a bigger speed-range than any known French machine.

On August Bank Holiday, 1914, some of the Great Powers of Europe were already involved in war; but Great Britain had not entered the conflict. It was considered inevitable that she would, and the aviation meeting at Hendon on that day was distinctly overshadowed by the clouds of war. The programme was followed in a perfunctory manner, and the one topic of conversation was the rumoured movements of troops, the purchasing by the Government of vast quantities of material, and the sudden reported famine in petrol. But the universal feeling of gloom was due to a general dread lest the British Government should shirk a conflict, betray Belgium, and, by so doing, ensure the certain downfall in disgrace of the Empire. Most of the civilian aviators present had, within the past few hours, responded to the appeal of the Chairman of the Royal Aero Club, the Marquis of Tullibardine, for volunteers in view of the probability of war.

That evening the issue still appeared to the general public to be in doubt, and on their return to London the crowd from Hendon read with mixed and uncertain feelings the brief official announcements, for a great many people thought that these revealed the existence of division and vacillation in the Cabinet. But on the following day doubts were set at rest. It was not long before many of the aviators who had volunteered their services were on their way to France, there to win glory or death.

The Italian Tripoli campaign and the Balkans wars had not afforded a solution of a single one of the numerous vexed questions relating to the use and limitations of aircraft in war. That aeroplanes had been used with good results in reconnaissance, and that they had on many occasions been struck by bullets were quite inconclusive circumstances. The lessons, such as they were, applied to the employment of aircraft in the Army manœuvres and mobilization tests of 1913 and 1914 were, within a few weeks after the outbreak of the Great War, proved almost useless, as will presently be shown.

Before summarizing the aerial equipment of the Powers, it will be well to glance at the capabilities of aircraft of the time. In this regard records in speed, altitude, and duration must be mentioned, although they have only an indirect bearing upon usefulness in the field.

The fastest speed that had been attained on an aeroplane not aided by the wind was 126½ miles per hour; but this was on a machine that had very little range of speed, and that could not safely land except on a smooth ground about 800 or 1000 yards long. It was not a war machine, and comparatively few pilots could fly it, or machines of similar qualities. Aeroplanes were, however, being made with a maximum speed of 100 miles per hour, and even slightly more, that would keep in flight at forty-five miles per hour and were, therefore, by no means mere racers. There were several types having a big range of speed, with the maximum well over ninety miles per hour. To this class belonged the Avro, Sopwith, and Bristol "scouts."

The altitude record was 25,756 feet, but such a height could not be attained without special preparations, and was merely serviceable as showing that there was no actual impossibility either to man or machine in flying at very great altitudes. Far more important was the fact that heights of 10,000 and 12,000 feet were commonly attained, and that a climbing speed of 1000 feet in a minute for the first 1000 feet, with a fair load, had been realized.

Flights of over twenty hours' duration had been made on several occasions; of course, with every ounce of spare carrying capacity given to fuel and oil. Against these extreme cases may be set the fact that many aeroplanes, besides pilot and passenger and something to spare for ammunition, could carry enough fuel for a seven or eight hours' flight.

The altitude and duration records were held by Germany.

As to the capabilities of aircraft, more will be written when the equipment of the belligerent Powers is detailed.

Although written four years before the war, the author's following summarization of the functions of aircraft fairly expressed the view of the military authorities in 1914. The summarization is here repeated.

The usefulness of aerial craft in war are as follows, according to the nature of the vessel:—

CAPTIVE BALLOONS AND KITES

To discover the strength and position of the enemy. To survey country. To observe the approach of submarine vessels and to detect the presence of mines. To deceive the enemy as to your position. To signal over great distances when wireless telegraphy is not available.

FREE BALLOONS

For reconnoitring purposes generally, using photography on occasion. For the transport of persons and mails out of besieged cities. For throwing explosives on the enemy.

DIRIGIBLE BALLOONS

All the foregoing services can be performed by dirigible balloons, in some cases far more effectively. Further, they can be used for the swift transport of small bodies of men, and for organized attack on fortified places.

AEROPLANES

Chiefly for reconnoitring purposes, and for acting in conjunction with dirigible balloons in attacking fortified positions, when exceedingly rapid movements are necessary. The use of the aeroplane is limited at present owing to its small weight-carrying capacity. But its great advantage is that on numerous days when the elements make operations by dirigible balloons impossible the aeroplane will be able to work safely and surely. For military purposes there is need for an aeroplane containing some adaptation of the helicopter or other principle enabling it to hover as well as to fly over a place. Many inventors are seeking to perfect some such machine.

It is extremely interesting now to recall the rules for aerial observation in manœuvres set up by the War Office shortly before the war. Aircraft were to fly as a rule at not less than 3000 feet when exposed to rifle fire, and when artillery was underneath them this altitude was to be increased by another 1000 feet. Under misty conditions it was left to the pilot to drop lower if objects could not be distinctly seen. It was admitted that, as a rule, observers in aircraft were able to judge whether they were under fire or not.

The General Staff Notes were as follows :—

(1) The accurate observation of bodies of troops largely depends on two circumstances: (a) The background, that is, the colour of the ground on which the troops may be at the moment; and (b) Movement, i.e. troops on the move are far more easily seen than when they remain absolutely still.

(2) A column of troops moving along a white or light-coloured road can be easily seen from almost any height, whilst an extended line of infantry scattered on the grass amongst small bushes will seldom be detected if they remain still. Troops should on no account look up at aircraft, for nothing is more conspicuous than men's faces.

(3) When troops are marching along a broad road it is advisable that strict march discipline be maintained, the troops being kept well to one side of the road, so that the remaining side, if kept absolutely clear, will look like the whole of the road, and will probably not attract the observers' attention.

(4) Troops in column of route on a narrow road may escape observation if they at once take cover on either side of the road and remain absolutely still, close under the hedges.

(5) Woods, belts of trees, high hedgerows and villages all offer complete shelter from observation if taken advantage of when the aircraft is still at a distance.

(6) When moving over country in extended order or in small columns, troops should take cover under the nearest trees, hedgerows, or patches of gorse and bushes, lying still, close under the edge of such vegetation, until the aeroplane has passed on.

(7) Formed bodies of infantry must be got under trees or into woods if they are to escape observation, for in the open they are certain to be seen.

(8) Artillery will probably be unable to conceal either their guns or their horses, except in very favourable country where trees are numerous and the view much

restricted. Guns in the open will no doubt be easily seen, and the only hope of concealment is to occupy a position close up to a hedgerow and fire through it.

(9) When troops are in camp, or in bivouac, every endeavour should be made to alter the usual formations with a view to deceiving the observer and causing him to mistake one unit for another, e.g. a battery for a Field Company, R.E. Guns can be covered with tarpaulin or hay. Where feasible, cooking should be done near villages, so that the smoke does not attract attention.

(10) The question will often arise as to how long the presence of a hostile aeroplane is to be permitted to interfere with or paralyse the manœuvre which may be in progress. Time may be a more important factor than discovery, and brigade commanders must judge whether it is more advisable to delay the movement by taking cover and remaining hidden, or to continue the manœuvre.

Further revealing the anticipations of British military authorities may be quoted the War Office tests for the guidance of manufacturers issued in February, 1914.

The tests, set out on the next page, included an examination of workmanship and materials, rolling test, and one hour's flight. For purposes of calculation weights of pilot and passenger were to be 160 lbs. each. Stress diagrams in duplicate for the aeroplane were to be sent with, or before, the machine. A minimum factor of safety of six throughout was essential. No machine was to be tested for military purposes unless it fulfilled the conditions of one of the types used for military purposes, as given in the table. The applicant had to state his reasonable expectation of the performances of the machine. The aeroplanes had to be put through the whole of the tests unless damaged before their completion, or unless the Chief Inspector considered that the tests should be stopped for reasons of safety.

PERFORMANCES REQUIRED FROM VARIOUS MILITARY TYPES.

	Light Scout.	Reconnaissance Aeroplane (*a*).	Reconnaissance Aeroplane (*b*).	Fighting Aeroplane (*a*).	Fighting Aeroplane (*b*).
Tankage to give an endurance of	300 miles	300 miles	200 miles	200 miles	300 miles
To carry ..	Pilot only.	Pilot and observer plus 80lb. for wireless equipment.	Pilot and observer plus 80lb. for wireless equipment.	Pilot and gunner plus 300lb. for gun and ammunition.	Pilot and gunner plus 100lb.
Range of speed	50 to 85 m.p.h.	45 to 75 m p.h.	35 to 60 m.p.h.	45 to 65 m.p.h.	45 to 75 m.p.h.
To climb 3,600ft. in ..	5 minutes.	7 minutes.	10 minutes.	10 minutes.	8 minutes.
Miscellaneous qualities	Capable of being started by the pilot single-handed.	—	To land over a 30ft. vertical obstacle and pull up within a distance of 100 yards from that obstacle, the wind not being more than 15 m.p.h. A very good view essential.	A clear field of fire in every direction up to 30deg. from the line of flight.	A clear field of fire in every direction up to 30deg. from the line of flight.

Instructional aeroplanes with an endurance of 150 miles will also be tested under special conditions; safety and ease of handling will be of first importance in this type.

This is of extraordinary interest now, as illustrating the general possibilities of aircraft at the time, and particularly in view of the fact that three classes of fighting aeroplanes were specified. At that time many experts supposed that aeroplanes of the types then extant would never fight in the air, that they would, on the contrary, always avoid conflict. It is a fact that the British "Fifth Arm" entered the field with many machines better adapted to fighting than those of the other Powers, and the tests quoted above are proof that the British authorities had, in one detail at any rate, a clearer conception of the coming aerial war. Duels in the air occurred immediately after the outbreak of war. In a later chapter this development will be examined.

As if in anticipation of the great ordeal that was so soon to come the Army manœuvres of 1914 of all the Powers brought together unprecedented numbers of aircraft on a war footing.

A test of the organization of the German Flying Corps was made in May. Three aeroplanes were ordered to be sent to Doeberitz from each of the centres at Cologne, Posen, Königsberg, Halberstadt, Metz, Strasburg, Darmstadt, and Graudenz, each about 300 miles distant. With the exception of the three from Darmstadt, which were stopped by a storm, all the machines reached their destination in good order.

In France squadron flights were at all times in progress.

In England a concentration of aeroplanes was made on Salisbury Plain. Five squadrons, each of twelve machines, were assembled, with transport. Three of the squadrons had their complete road transport, namely, thirty-eight vehicles each. There were other but incomplete units, and altogether about seventy aeroplanes and two hundred motor vehicles were assembled. The exercises included speed tests, reconnoitring for named objects, climbing tests, wireless, photographing, and night-flying.

The Royal Naval Air Service at about the same time had an assembly of machines at Spithead, about twenty seaplanes taking part. Striking displays over the fleet were made, and a "flight past" the King during his inspection was duly performed.

At this period the Royal Naval Air Service had control of all lighter-than-air craft and all seaplanes, and possessed in addition a number of "land" aeroplanes, and the Royal Flying Corps was confined to "land" aeroplanes.

Meanwhile tentative steps had been taken to protect warships against aerial attack. The new "Temeraire" was fitted with light horizontal armour plates over her magazine. The magazine is obviously a vulnerable point, and once made safe the armoured ship had little to fear from such aerial attacks as were then considered possible. Later ships were similarly protected, and a few high-angle guns were distributed among the Fleet.

Seaplanes were, relatively to overland craft, less developed, and were not yet capable of regularly getting off and alighting upon rough water, or of weathering life afloat for many hours. Their structural heaviness made them slower and poorer climbers. As befitting her maritime supremacy, Great Britain was at this time ahead of other countries in the development of the seaplane and, as related elsewhere, had won the important international Jacques Schneider contest at Monaco. The winning boat was not a true seaplane, however, but an overland craft with floats.

When war broke out the most conflicting estimates were published as to the strength in aircraft of the belligerents. It was extremely difficult to arrive at an exact estimate, and the only way to attempt it was to consult the best authorities as to their strength before war made it imperative to withhold information relating to armaments.

So far as Great Britain is concerned accuracy is possible. The machines assembled at the concentration on Salisbury Plain in July, 1914, were very nearly all that the country possessed in a fit condition, and the same may be said with regard to the seaplanes in the Solent.

These craft included B.E.'s (Blériot Experimental), S.E.'s (Scouting Experimental), R.E.'s (Reconnaissance Experimental) of various kinds designed and largely made by the Royal Aircraft Factory; H. and M. Farman biplanes; and a few Avros and Sopwiths. The monoplane was scarcely represented beyond a few Blériots. The seaplanes were Farmans, Wights, Shorts, and others. Of airships Great Britain possessed an Astra-Törres, a Parseval, and two small craft. A large rigid airship was partially built.

France, it is believed, took the field with about four hundred aeroplanes, and four first-class airships and a number of smaller dirigibles.

Approximately the strength of the Powers was—

		Airships.	
	Aeroplanes.	1st class.	2nd class.
Great Britain	130	2	2
France	400	4	10
Russia	400	4	3
Germany	470	18	6
Austria	120	1	3

In these figures all airships capable of a speed of forty-five miles per hour are ranked as first-class vessels. This division is arbitrary, but airships capable of high speed naturally possess other good qualities. The high-speed airships of Germany were not all of the rigid type; the later Parseval and Gross airships are included. The numbers given of aeroplanes are only approximate, for each of the Powers possessed many reserve machines. Very possibly Germany had more aeroplanes ready than appear on the list, for it is without doubt that she had been making secret preparations for a long time, and, according to one estimate, she was able to put about 1000 machines into the field.

In the transportation of the British Expeditionary Force to France the Royal Flying Corps created an aeronautical as well as a military record by flying three full squadrons—about forty aeroplanes—across the Channel, no mishap occurring. The general public knew nothing of this remarkable achievement save those who saw the actual flight off Dover one morning in August.

At the front the field organization was speedily disorganized in the great retreat upon Paris, during which, however, British aeroplanes rendered magnificent reconnaissance service and were largely instrumental in saving the allied armies from destruction.

During the early weeks of the war British aeroplanes and airships incessantly patrolled the Channel and Straits, safeguarding the transport of troops and munitions.

Germany had specialized on airships, but since 1912 had made strenuous efforts to excel her western neighbour in aviation. France had led the world in aviation, and for a few years had paid less serious attention to dirigibles, in which at one time she had been supreme. But supremacy on the sporting side of flying, and the consequent exaltation of false ideals, had caused France to manifest a tendency to rest on her laurels, and at the moment war broke out the Flying Service was in an unsettled condition; and the machines ready for war included an unduly large proportion of fast monoplanes. Indeed, a number of monoplane types of world-wide renown were immediately struck off the list, and efforts were made to reduce the diversity of types.

Russia had a great number of aeroplanes, comparatively few of which had been manufactured in Russia.

As to national types, the French were too much in love with the monoplane, albeit many excellent biplanes were made in France. Many of the Army machines were ured with 3 mm. chrome nickle steel plates under ilot's seat and the engine, and in a few cases at the also. Very little had been done towards arming lanes with machine guns, but the "pusher" type

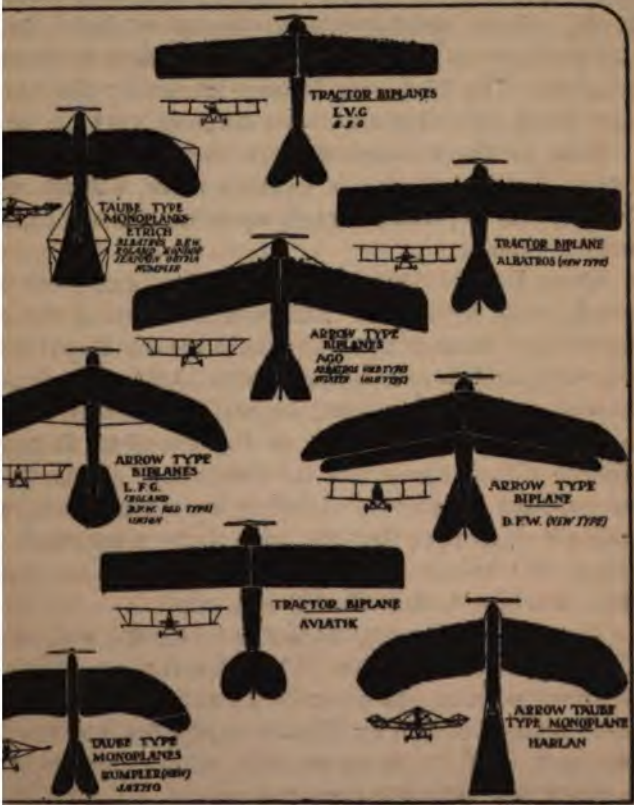


FIG. 45. GERMAN AEROPLANES IN SILHOUETTE "Flight."

plane, i.e. machines with the propeller and engine d the pilot, was easily adapted for this purpose. riments in this and in bomb-dropping were in pro-, and each year saw competitions in bomb-dropping rizes offered by Michelin.

Q

Germany had neglected armament, but had given close attention to bomb-dropping, and her machines were in most cases armoured. She specialized in natural stability by machines having wings with the leading edge sweeping back and with curves resembling those of the wings of birds. These machines were heavy of flight, but undoubtedly were restful for the pilot. Most of them were tractors. The bird-form became known as the "taube," and there were about a dozen different varieties of it.

Most of the German engines were water-cooled Mércèdes, but there was a German-made Gnome in use. France still depended largely upon the Gnome and other rotary engines.

Great Britain had many types of machine, but a relatively small aggregate. She possessed two or three very useful war craft in types designed by the Royal Aircraft Factory, and in even superior craft hailing from private manufacturers. For years she had had chances to acquire naturally stable machines in the excellent Dunne and Handley Page types, but the limitations rather than the advantages of natural stability were then seen, and it was not until 1914 that the advantages were emphasized, when the Royal Aircraft Factory type was procured. This machine is described elsewhere.

In anti-aircraft weapons Germany led the way, and had done so for many years. The French were, however, in a strong position when war broke out. Great Britain had done little save feed on illusion until a few months before the war, and for many months after deficiency in this respect was only too conspicuous.

The instructions to aircraft for peace manœuvre purposes quoted early in this chapter give no indication of the range of anti-aircraft guns of that period: they rather assumed that aircraft would be extremely difficult to hit. And the war soon proved that anti-aircraft guns are better than the gunners, who without long experience made very poor practice. In the first year of the struggle the Germans had, if not the best guns, at any rate greater numbers of them; and firing, as they did, by batteries systematically covering a large sky area, and with shrapnel bursting at different heights, they often scored hits at altitudes of 10,000 and 12,000 feet: it was, of course, quite a matter of chance if an aeroplane was struck in a vital spot.

Gradually, as the war went on, the average height of flying increased, but to effect their purpose pilots often flew far below the safety line, and in spite of heavy fire came down swiftly to less than 1000 feet.

It will be sufficient here to indicate quite briefly the range of anti-aircraft guns. A gun employed by the British Navy was a combination of anti-torpedo and anti-aircraft weapons. When required for work against surface vessels it had a range of 13,000 yards (between seven and eight miles), with 31 lb. shells, and the mounting provided for an elevation of nearly 80 degrees, at which angle its effective height range was 9000 yards (over five miles). At a distance of four and a half miles it could send its shell to a height of 13,000 feet. A smoke-producing powder was enclosed in the shell to enable the gunner to see the accuracy of his aim.

The Germans used a 10·5 cm. anti-aircraft gun capable of firing to a height of 26,000 feet. Krupps made several types; a 10·5 cm. gun for naval purposes; one of 7·5 cm., mounted on a motor-car; and a 6·5 cm. field gun. The first two guns could be elevated to an angle of 75 degrees, and the last one to an angle of 70 degrees. They had a maximum range of altitude of 11,500, 7,000, and 6,000 metres respectively. Other German ordnance firms made anti-aircraft guns.

It was early found that in order to drop bombs with accuracy aviators received little aid from the instruments of precision that at that time had been devised. In attacking airship sheds at Düsseldorf and Friedrichshafen British aviators flew as low as 600 feet.

To drop bombs with effect it is not necessary to fire them out of any weapon; the force of gravity gives sufficient velocity. The difficulty of designing an instrument for timing is seen at a glance when one considers the numerous factors that have to be allowed for. All bomb-timing instruments should be designed to take into account the two factors of the machine's speed (relatively to the ground) and its altitude. Early devices took into account only the machine's independent speed, and left to the pilot the task of calculating the speed and variation of the wind and making due allowance by consulting a prepared table. Also, their altitude allowance was based on the height over sea-level, so that the pilot had to know the elevation of the land over which he happened to be passing at the moment of firing.

For use from aeroplanes experiments had been made with small Maxims and with the well-known Lewis gun. Scarcely any weapon with a larger bore than the ordinary Service rifle was used, and the employment of heavier guns on aircraft was considered to be a matter for the future. By the end of 1915, however, machines were being made to carry bigger guns, although obviously the weight of the ammunition becomes a serious problem.

All these questions necessarily depended upon the average Service aeroplane, which in the early days of the war was a single-engine craft at the best combining a speed of about seventy-five miles per hour, a duration of six hours, and a capacity for ammunition of 150 lbs. to 200 lbs.

Grave doubts as to the utility of aircraft had been entertained, and certain high military authorities had been sceptical. The war provided the first practical test on a large scale in which the Powers most advanced in the development of aircraft were engaged, and it was evident from the beginning of it that airships and aeroplanes could be employed to some purpose. Their principal work was reconnaissance, but artillery fire-direction, bomb-dropping, and actual fighting were also among their activities. Testimony to their value was given by Sir John French in despatches, and the first of these, having peculiar historic interest by reason of its being the first general report on the use of aircraft in warfare, may be quoted here. At the end of his despatch, dated September 7, 1914, Sir John French wrote :—

" I wish particularly to bring to your Lordship's notice the admirable work done by the Royal Flying Corps under Sir David Henderson. Their skill, energy, and perseverance have been beyond all praise. They have furnished me with the most complete and accurate information which has been of incalculable value in the conduct of the operations. Fired at constantly both by friend and foe, and not hesitating to fly in every kind of weather, they have remained undaunted throughout.

" Further, by actual fighting in the air, they have succeeded in destroying five of the enemy's machines."

Important additional testimony to the same effect was given in later despatches, and details of the work done were specified.

In the despatches issued on October 18, 1914, Sir John French gave the names of thirty-seven officers and non-commissioned officers of the Royal Flying Corps who had up to September 18 rendered distinguished service.

The Royal Naval Air Service displayed great enterprise, and among the early events of the war were the raids of small parties of airmen, on September 22 and October 8, over Düsseldorf and Cologne. Bombs were dropped on the Zeppelin shed at Düsseldorf, and on the latter occasion the destruction of an airship was effected. At Cologne the railway station was damaged.

In orders dated October 21, 1914, four members of the Royal Naval Air Service were appointed to the Distinguished Service Order.

The Under-Secretary for War stated in Parliament on June 16, 1915 :—

"Since the outbreak of the war there has been an expansion in the number of pilots in the ratio of ten to one, and an expansion of men generally (of the Air Service) in the ratio of five to one."

Sir John French in his despatch of February 2, covering a period of rather more than two months, stated :—

"During the period under report the Royal Flying Corps has again performed splendid service. Although the weather was almost uniformly bad and the machines suffered from constant exposure, there have been only thirteen days on which no actual reconnaissance has been effected. Approximately 100,000 miles have been flown."

From Sir John French's despatch published April 14, and from the references therein to the work of the Royal Flying Corps, the following may be quoted :—

"In addition to the work of reconnaissance and observation of artillery fire, the Royal Flying Corps was charged with the special duty of hampering the enemy's movements by destroying various points on his communications. . . . Certain new and important forms of activity, which it is undesirable to specify, have been initiated and pushed forward with much vigour and success. There have been only eight days during the period under review on which reconnaissances have not been made. A total of approximately 130,000 miles have been flown—almost entirely over the enemy's lines."

In his despatch of June 15, Sir John French stated :—

"The Royal Flying Corps is becoming more and more an indispensable factor in combined operations. In cooperation with the artillery, in particular, there has been continuous improvement both in the methods and in the technical material employed. The ingenuity and technical skill displayed by the officers of the Royal Flying Crops, in effecting this improvement, have been most marked."

In the despatch published on November 2, and covering the period June 15 to October 15, Sir John French stated that the amount of flying done had been doubled during that period, and that 240 aerial duels had occurred in which our aerial supremacy had been fully maintained. He instanced various functions fulfilled by aircraft, and mentioned the fact that on one occasion an aeroplane continued its work in spite of 300 bullet-holes.

An official statement of the work of our French Allies estimates that from the outbreak of war till January 31, 1915, the French Flying Corps made 10,000 reconnaissances, during which a total of 18,000 hours was spent in the air, and the aggregate distance flown was 1,125,000 miles.

Aircraft were in use in every theatre of the war—in the Dardanelles, on the Russian front, and on the Italian front, and the Japanese used aeroplanes with success at Tsing-tau.

The war was prolific of incidents, tragic, pathetic, heroic. Above all things it made manifest the beauty and glory of flying. Of this an incident related by the Cairo Correspondent of *The Times* on March 13, 1915, is eloquent.

"One soldier, a placid and kindly-looking Anatolian, had the following strange story to tell:—

"'I was two days without food by the canal. The others had food, but I had none. I was an officer's servant, and my officer said he would see that I had food, but I had none. While we were near the canal a *tiyaré* (aeroplane) came flying over us. My officer said, "Shoot, shoot." But I did not shoot. I never had seen a *tiyaré* before, and it was going so beautifully, like a bird. He said, " Shoot " again, but I wanted to look at it. Then he was very angry, and we had an altercation. So I shot my officer. I did not want to shoot the aeroplane, it was going so beautifully.' "

The wonderful development of aerial warfare during the great death grapple of the Empires must be considered in other chapters, together with a few of the technical aeronautical victories and estimates of the real bearing of the " Fifth Arm " upon warfare on sea and land. Here it must be placed upon record that early in the war British artillery officers as a rule had little faith in the efficiency of aerial observation, and the Royal Flying Corps and the Royal Naval Air Service found a difficulty in co-operating with them. This was the more remarkable in view of the fact that as regards the use of wireless telegraphy—so important to aircraft operations—the British were ahead not only of the Germans but also of the French.

CHAPTER XVI

AIRCRAFT AND RAILWAYS

FROM the military point of view, perhaps, the most important of all the bearings of aircraft—possibly not excepting even reconnaissance—concerns the vulnerability of railways to attack from above. Very early in the Great War the airmen of the Allies were sent up with orders to harry the enemy's railway communications by bombarding the lines, destroying bridges and culverts, and in other ways temporarily dislocating traffic. The war was to a very great extent a war by railway. Without the use of close networks of railways the struggle would have lost much of its intensity. Mechanical road transport was a big factor, but the railroads stood first in the rapid conveyance of men and material from one point to another. Only when the weather was dry, and the condition of the roads facilitated motor transport, were the railways efficiently seconded.

Scores of important raids on railway lines were made by British and French airmen. Among these may be mentioned a British airman's attack on Haltingen about April 17, 1915, when 100 metres of goods line was destroyed; the raids on Müllheim and Habsheim on April 20, when stores were fired; the destruction of Courtrai Junction on April 26, in which the late Sub-Lieutenant W. B. R. Moorhouse won the V.C. and lost his life; the bombardment of the stations at Tourcoing, Roubaix, Ingelmunster, Staden, Langemarck, Thielt, and Roulers; of the junction at St. André and the canal bridge at Don on May 8; of St. Quentin early in April, when a train laden with petrol and ammunition was destroyed; and the destruction of the railway bridge at Douai: and the list could be extended to the length of several pages.

In considering this matter the first question that arises is as to the effect of the dislocation on the traffic, and the time occupied in putting the lines into work again. As will readily be understood, a delay of only a few hours may cause serious embarrassment, and the blocking of railways at certain points at the right moment might, in combination with other operations, paralyse the enemy completely and facilitate his defeat. Generally speaking, permanent way can be restored by a few hours' labour, provided an efficient organization be available.

The most vulnerable points of a railway are the bridges by which it crosses rivers and roads: break one of these down and a long delay will be caused. These points were jealously guarded and watched, in many cases an aerial patrol forming part of the defence, as at the bridges across the Rhine. The most serious damage to the ordinary line is effected by the wrecking of a fast-moving train, which makes havoc of the permanent way for some distance; but this is difficult to effect except by a lucky shot.

On one busy day no fewer than six enemy trains were partially wrecked. But it was generally found that the amount of damage done to the permanent way by bombs of 100 lbs. or less was quite small. Weather seldom hindered the attacks on railways, for these occurred on several occasions in gales of fifty miles per hour.

An instance of the dislocation caused was provided by one of the aeroplane attacks on Don, as a result of which the Germans in some miles of trenches went without their rations for one day.

In dry weather there is alternative transport to railways, but that does not make railway-wrecking unnecessary. Railways are the heaviest load routes, and by far the quickest except for very short distances. Moreover the needs of a modern army are so vast in the matter of supplies that all the means of transport are used up to the fullest extent, and still more are needed. Any dislocation or delay of any portion is therefore serious. And just as it is desirable to prevent the enemy from concentrating for attack or defence, so it may be important to hinder his retreat when defeated.

In times of peace in the future it will be just as necessary to organize a system of defence for railways against attacks from the air as it is to protect important harbours by guns on land and floating batteries. In future wars one of the first things to be done will be to delay the enemy's mobilization and concentration of troops by crippling his railway system at a few vital points. Before any declaration of war the side that most seriously means business will take this step in spite of international laws, and the need is therefore great that the aerial arm should be increased mightily in order to provide adequate defences. These defences must be by means of carefully placed batteries of anti-aircraft guns, and by the stationing of squadrons of aircraft ready for action where they are likeliest to be required.

The power of aircraft seriously to delay the concentration and advance of armies is one of various factors that increase the importance of the "Fifth Arm." It means that war will begin with a fierce struggle in the air between attacking aircraft and the defences of railways. If it should be possible for one side to assert such a degree of supremacy in the air that it could, even at considerable loss of men and machines, delay the enemy's mobilization and concentration, at the same time protecting its own armies from aerial molestation, it would have gone a very long w towards ensuring victory even though numerically w er.

The nt need not be laboured: it is perfectly clear. And it ne would be sufficient to ensure that the first line of ence and defence of all countries, insular or contine l, will be the aerial arm.

CHAPTER XVII

AIRCRAFT AND SUBMARINES

WITH craft whose capabilities are so continually improving as are those of airships, aeroplanes, and submarines it is impossible to indicate definitely their mutual bearing in war. On the facts that an aerial observer can see objects beneath the surface of the sea at a depth of 20 or 30 feet, that bombs can be dropped from aircraft, and that submarine craft cannot dive at an instant's notice, it was formerly argued that aircraft would be an effective antidote to submarines. That in combats between the two aircraft are in the stronger position is clear, but in practice, as the Great War soon showed, it is virtually impossible to provide a force of aircraft in sufficient strength to make submarine work impracticable.

The Great War did not provide material for final and definite opinions on quite a number of intensely interesting problems. One lesson was taught, and that was the greatness and loneliness of the sky, and also of the seas which look so small on the map. A landsman who has never crossed the North Sea from London to Ostend—leaving long ocean voyages out of account—has no idea of the waste of waters, and before the war he would have utterly failed to understand how it was possible for a big squadron of battleships to escape observation. Equally so would the man who has never travelled in the air fail to understand how a great airship could cross the North Sea, drop bombs on English towns, and get away again without being seen by more than a very few people. This lesson of the vastness of the seas and of the ocean of air must be kept in mind when considering the work of submarines and aircraft, and with these modifications: (1) that the ocean of air is more easily observed, when not overcast by clouds, but that the craft which navigate it are five or six times as fast as submarines; (2) that the seas are less easily examined for the presence of submarines, but that these vessels have only about one-fifth or one-sixth of the speed of aircraft.

In view of these considerations it is not surprising that British aeroplanes, although sent out to hunt for submarines, have been within a few miles of them when they have attacked British and neutral ships and yet have failed to see them. These craft can be seen by an observer overhead when at a depth of as much as 30 feet, even in the North Sea and Channel. Over calm water with a white bottom they can be seen to an even greater depth. But submarines avoid as much as possible travelling totally submerged, and when awash, or even with only the periscope above water, they are much more visible; in addition, they then leave a wake, which should often help to reveal them. The observer above need not be directly overhead to see the completely submerged craft, but he must be nearly so. Up to a certain point the higher he is the better he can see, and the larger the area of water over which his effective vision extends.

The submarine's range of action is greater than that of the aeroplane or of most airships. Aeroplanes can travel in any weather that the submarine will venture out in; but the airship is not so weather-worthy. Yet it may be taken almost as a rule that aircraft can venture out in any conditions that keep the sea calm enough to make the observation of submarine craft possible.

These considerations apply, of course, only to sea and aircraft of the present day, which may be totally altered in the near future, and they merely serve to show that aircraft observation of submarines at sea can at present only be of the most superficial character, and until the side interested could spare for the purpose a vast fleet of aircraft—a fleet numbering not hundreds but thousands —submarines have a good chance of escaping detection even in the narrow seas round Great Britain.

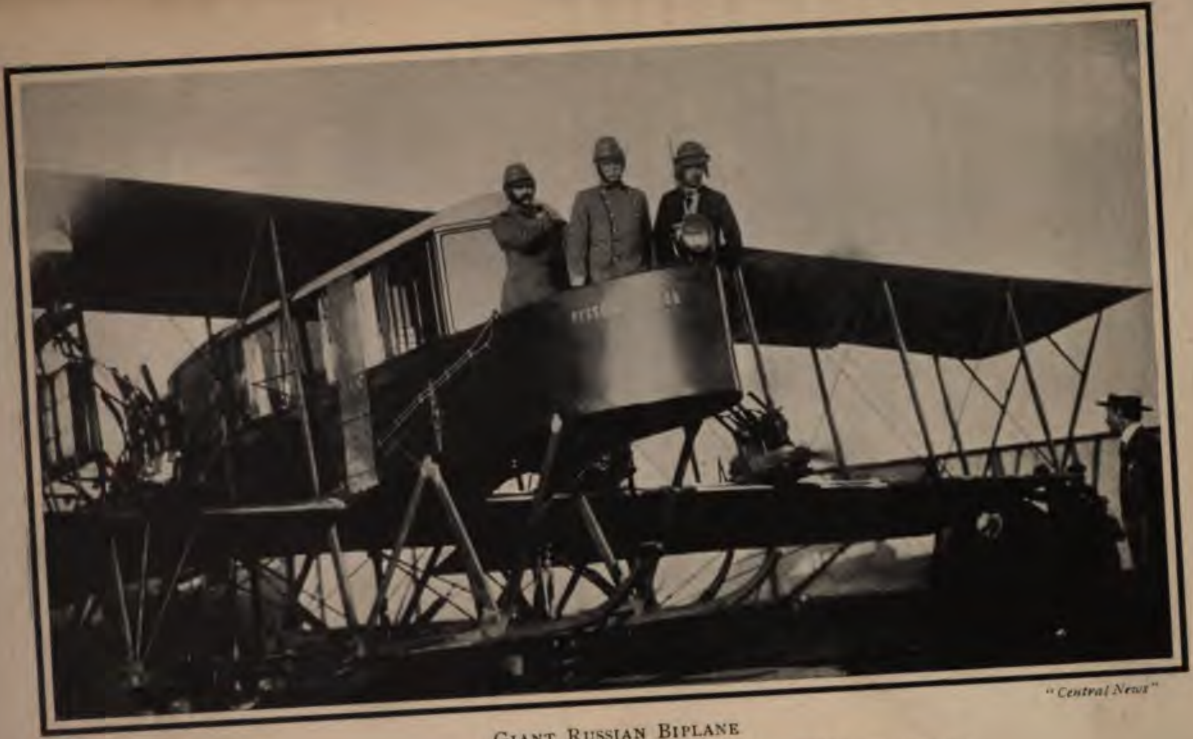
That, however, does not imply that it is of no use to send out aircraft until thousands can be spared. It may, on occasion, be of supreme importance to be able to locate a single enemy submarine, and to be able to convey the intelligence to the right quarter. It is, then, worth while to use any means available.

At present it may be taken that no power of serious offensive is possessed by the submarine against aircraft. The former, it is true, can carry small guns besides their torpedo tubes, but the effectiveness of one gun has been proved to be almost negligible. And to use weapons of the kind, the submarine must come to the surface, when it is at once exposed to attack. Even if its opponent were only one aeroplane, the submarine would probably get the worst of it. The aeroplane could with safety venture low enough to drop bombs on the quite large mark offered by the submarine, whilst if it were armed with a machine gun it might easily inflict enough damage to put the submarine temporarily out of action. Even if the submarine remained below water, but visible, a bomb dropped from a height of 500 feet or more would probably have a destructive effect. And this attack is likely to be the more deadly from the use of a bomb fitted with a fuse adapted for exploding at a given distance below water instead of on contact with the surface.

For the reasons that the airship can carry a bigger magazine than the aeroplane, and that it can adjust its speed to that of the submarine without getting below its minimum speed, which is, of course, zero as against the forty miles or so of the slowest aeroplane, the airship is the more effective anti-submarine craft.

Aircraft are equipped with wireless apparatus, and a function of the submarine hunter will be to give notice of the locality of any submarine seen, so that destroyers can hunt it down, and transports and merchant craft can give it a wide berth.

There is one point, of course, at which aircraft and submarine can meet, greatly to the disadvantage of the latter; and, as it is hardly necessary to remark, this is at the building yard. The utility of aircraft was seldom more strikingly shown in the war than in the British raids on the enemy's submarines at Zeebrugge and Hoboken. It is to be observed that a submarine can be very materially damaged by the comparatively small bombs carried by aircraft, whereas a battleship would only sustain surface damage. Of marine craft, then, the submarine is the aeroplane's natural prey. In one raid at Hoboken two submarines were destroyed and a third damaged. It does not follow, of course, that airmen could account for submarines under construction at a well-protected place such as Plymouth.



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CHAPTER XVIII

BATTLES IN THE AIR

It would be idle to deny that the principal use to which aircraft have been put is that of war, and therefore in reviewing the position of aeronautics prominence must be given to this aspect of it. In order to understand the present capabilities of aircraft clearly, and to realize their possibilities in peace, this must be taken into account, but always with one reservation, namely, that Governments and men are compelled to go to extremes in expenditure and daring for war that would be thought without justification for any other end.

The Great War made one demand upon aircraft that none were specifically designed to meet: it was quite early in the conflict seen that duels between opposing aeroplanes were inevitable in the nature of things, and deliberately sought by the more enterprising aviators of the Allies. The latter possessed machines not markedly better adapted to fighting in the air than the enemy's, but for a time the great majority of the aerial duels that took place were forced on enemy airmen against their will.

Designers had planned machines for carrying guns, but none of the belligerents had actually adopted these types as standard Service craft. In this respect, however, the British War Office were, as to theory at any rate, more advanced than the War Departments of their Allies or their enemies, and in the specifications of aeroplanes required for the Service published by the British authorities in the spring of 1914 three types of fighting aeroplane (see page 241) were described. At the time war broke out this offer, for one reason and another, had unfortunately not been taken advantage of.

Infinitely various are the aerial combats possible where machines of widely different speed, climbing power, and "fighting trim" are opposed to each other. By "fighting trim" the author refers to the facilities given to pilot and passenger for firing at an opponent, and it chiefly concerns their relative positions in the aeroplane, and the "fire field" available.

Before the war the Germans paid little attention to aerial fighting; they decided that no effective work could be done with a gun from an aeroplane, and they confined their offensive plans to bomb-dropping. The majority of their aeroplanes were tractor monoplanes and biplanes; and in most of them the passenger sat in front of the pilot, the latter being able to look down over the rear edge of the wing, and the former having a good view ahead, although unable to fire any weapon forward on account of the propeller. When these craft were forced to fight, the pilot used a rifle or a revolver, abandoning the controls for the few seconds necessary; and it should be observed that with nearly all the German machines, so many of them being naturally stable, this was comparatively easy. But the pilot could only fire on either side, and with a very limited range. The Germans had a few biplanes of the propeller-behind division, and an important exception to the main types mentioned above was the D.F.W., in which the passenger sat behind the pilot, and had a fairly good fire-field on either side and behind.

An actual example of the duel in the air was related by an authoritative witness, namely, the officer attached to the British Headquarters Staff, who, writing on October 16, 1914, described how a Royal Flying Corps airman on a fast scouting monoplane, and carrying two rifles fixed one on either side of his engine, sighted a hostile machine and gave chase, but lost sight of the enemy in clouds. Then a German Otto biplane came into view, a comparatively slow "bus," but one having the engine behind, and, therefore, if well armed, a formidable opponent.

The narrative gives a vivid impression of this hunting in cloudland, which far exceeds in intensity of action anything ever experienced before in the way of sport—either man-hunting or beast-hunting.

The Englishman started in pursuit. He knew that, owing to the position of the propeller on the hostile craft, he could not be fired at when astern of the chase. When within sixty yards he fired one rifle without result. His superior speed taking him ahead of his quarry, he turned, and again getting astern emptied his magazine at the German, and the latter began to descend. Then the Englishman stopped his engine, and began a vol-plané whilst recharging his magazine. Unfortunately, it jammed, but he managed to insert four cartridges and to fire them at his descending opponent, who disappeared into a bank of clouds.

The English machine on that occasion had the advantage in speed; but this was not always the case. In one encounter three British aeroplanes gave chase to a German, but the one machine of the three that was faster than the enemy was forced to descend through engine trouble.

At the time it was apparent that the engine-behind machine was the best adapted for fighting. If one of these, armed with a machine gun, is opposed to a tractor with the passenger seated between the engine and the pilot, and it can get in front, it can fire without fear of reply. Such a position could only last for a few seconds while the machines were within effective range, but during that brief period an enormous advantage would lie with the "pusher."

But no machine can carry an unlimited supply of ammunition, and the moment comes when the enemy, unless crippled, can take the engine-behind craft in the rear. This, of course, is a manœuvre that requires skill, because almost certainly the "pusher" machine is the slower of the two and is soon left behind, and its opponent must fetch a wide sweep round. Meanwhile, the other will do its utmost to avoid being caught in the rear, and, well handled, may succeed in the manœuvring game almost indefinitely. High speed is, in almost every case, a huge advantage, but it has one drawback in those types of aerial craft which are not able to go slow or fast at will. On one occasion a Vickers fighting biplane was overtaken by a Fokker but beat it in fair fight.

Both parties to an aerial fight must ever keep an eye on their whereabouts; they are ever drifting leeward at more or less speed, and usually to one or the other this drifting carries the fight towards the enemy's lines.

The full story of the fighting in the air during the Great War would fill volumes. Here only a few incidents can find a place.

Captain Hawker, of the Royal Flying Corps, was on one occasion flying a Bristol scout when he encountered a German aeroplane over Hooge, at a height of 10,000 feet. Approaching down sun, his opponent thus having the light in his eyes, he opened fire at a range of 100 yards, and the enemy craft took fire and was destroyed.

The same pilot over Bixhoete, at a height of 9000 feet, approached a German scout biplane unperceived, and opened fire at 50 yards' range, bringing the enemy down.

But that was by no means a record short range for aerial duels, for in several cases machines have passed each other at less than 20 yards exchanging streams of bullets. Imagine two ninety-miles-per-hour machines passing in that fashion, the relative speed being 180 miles per hour!

Lieutenant Williams and Lieutenant Hallam on a B.E. 2c, near Lille, were attacked by a Fokker with a deflector propeller at a height of 7000 feet. Hallam was hit in the left hand, which prevented him from using the gun. After much manœuvring the pilot was hit in the arm and shoulder, and lost consciousness. The machine then started spinning, and Hallam climbed over between the two back struts and got hold of the control lever. This was not working. He then tried to close the throttle. This did not act, the wire being broken. He cut off the petrol, and then got the machine into control and landed in the French lines.

A B.E. 2c absolutely beat off two Fokkers, although during the fight a gun had to be moved to the rear of the machine. One of the enemy craft was destroyed.

Two R.F.C. officers on a B.E. 2c were attacked by an Aviatik, a much faster machine. The latter "made rings" round the British flyers, while both sides were firing continuously. The German then threw over two silver balls, which burst into smoke. The British pilot guessed these were altitude indicators, and promptly flew to a higher level; and only just in time, for immediately the enemy anti-aircraft guns fired a number of shells which burst just below them.

Enough has been said to show that many problems must be promptly solved, and how great is the need for swift and sure mental processes. Here, too, the skilful flyer is seen to advantage, and even the trick-flyer may bless the experience gained in performing thrilling feats in the aerodrome. The aerial duellist should be able to do everything that can be done on an aeroplane; he should be able to bank almost vertically, and turn almost within the span of his machine. One can almost conceive a situation when looping the loop might save a situation, although that kind of manœuvre is not usually expected of a war machine.

The tractor type of aeroplane—that is, the machine with propeller in front—possessed obvious disabilities when need arose to be able to fire a machine gun, which was in that type restricted to firing from the rear. Much ingenuity was exercised to overcome this difficulty, and it fell to one of the Allies' airmen early in 1915 to invent the "deflector propeller."

The gun is in a fixed position behind the propeller, with its muzzle pointing forward just above the boss. In the case of a two-bladed propeller, in the course of one complete revolution, the period during which the arm of the propeller, instead of open space, would be opposite the gun muzzle would be no longer than about 2 per cent —that is to say, if making 1000 revolutions in a minute the gun, firing a continuous stream of bullets, would find no obstacle for 58½ out of the 60 seconds; in the other 1½ seconds the bullets would hit one or the other of the two arms and scatter over the machine, damaging it or hurting the pilot, as well as, in all probability, breaking the propeller.

To prevent this each of the propellers has a very small deflector at that point of the blade that is struck by the bullets, and this deflector—merely a small metal plate—turns the bullet off so that it passes through, clear of the machine, but, of course, wide of its mark. This occasions no appreciable jar to the engine, and merely means the wasting of a small percentage of bullets. Thus, if one hundred bullets are fired in a minute two go wide.

The marksman is handicapped, inasmuch as he must head straight for his opponent when firing, but it also means that the pilot can steer his craft and fire the gun himself, so that the machine may be a light, speedy one-seater as well as a fighter.

Until this simple device was invented ingenuity was racked to contrive an elaborate and complicated arrangement by which the propeller stopped the gun at the moments when the field was obstructed by its blades. The enemy was using such a contrivance, and the French also until the deflector propeller was suggested.

Writing in the *Revue de Paris* in January, 1916, M. Jacques Montane dilated upon the courage demanded for a duel in the air.

" There are two men, two wills : the pilot and the man with the machine gun. Sometimes the same man fulfils both functions. They watch the adversary, armed as they are, perhaps better, ready to meet them, and the adversary may have the luck. One of the combatants must inevitably be dropped—no matter. The enemy aeroplane is yonder above our lines to effect a bombardment, to find our batteries or other objectives. He must be stopped from returning home. The aggressor tries first to cut off the retreat, then hurls himself forward, manœuvring to come on the side of the foe. At twenty or thirty yards the gunner, who has been waiting feverishly for the moment for opening fire, and has been receiving the enemy's fire without replying so as not to waste ammunition, rises, adjusts the machine gun, and begins tearing off his cartridge band. To avoid vibration the pilot stops the motor, and planes. The gunner acts as if duck-shooting and keeps his gun perfectly still. If you follow a machine you risk missing it, but if the fire is constant a moment will infallibly arrive when the enemy machine will come into the field. Bullets go on whistling round the ears of the pilot and his comrade. The gunner remains cool, unwrapping his cartridge rolls, and the pilot guides the aeroplane, flying jerkily to put off the adversary and to help his colleague. He gets nearer, and at last he is hit. Sometimes fifty minutes have been spent to get in the shot. Either it has struck a vital part of the mechanism or the pilot himself. The machine turns in the air and falls like a stone. Death usually follows, but one curious case is quoted. The pilot of a German biplane was killed in the course of an air duel, and his observer avoided death by bending over the corpse and seizing the controls just as he was landing. Nothing was broken.

"Sometimes the scout's duty is not to bring down the enemy, but merely to put him to flight. Thus Sub-Lieutenant J. fought with ten enemy aeroplanes that were coming to bombard Nancy and forced them to retreat. He charged each of them and as soon as one was turned charged the next. He could easily have brought down one or two aeroplanes, but he realized that that was not his duty. What he had to do was to prevent the aeroplanes reaching Nancy, and he succeeded alone, against twenty enemies, ten pilots, and ten bomb-droppers."

Aeroplanes specifically designed for fighting did not take the field until late in 1915; and early in 1916 machines carrying 3-inch guns—aeroplanes of a gross weight of some ten tons—were being made. In fact a great number of different types of fighting aeroplanes were evolved, from the big-gun type to the fighting scout, of which the Allies possessed three or four varieties.

Each side sought to spring aircraft surprises on the enemy. Thus, the Germans, finding themselves handicapped by lack of a fast fighting scout, evolved the famous "Fokker" armed monoplane, which was simply a high-powered machine with a tractor propeller fitted with the deflector already described, and a machine gun.

So far only duels between aeroplane and aeroplane have been discussed, but the relative fighting qualities of airship and aeroplane must be considered.

It was commonly believed at one time that the most powerful type of airship—the Zeppelin—would be driven from the skies by fighting aeroplanes, and to avoid the latter the Germans employed their airships for raiding purposes almost entirely at night, and they found that in darkness they enjoyed almost complete immunity, and that aeroplanes sent up to fight them could not find them in the dark, and in any case could not climb quickly enough to get the upper berth. These remarks refer, of course, to the comparatively short-range types of aeroplane available in the first eighteen months of the war and not to big multiple-engine craft capable of staying aloft all night, and not dependent upon the moods of a single power unit, that were then being designed.

The first fight to a finish between an airship and an aeroplane was that in which Flight Sub-Lieutenant R. A. J. Warneford brought down a Zeppelin that was on its return from a raid on England. The event showed clearly that the Zeppelin, despite a layer of non-combustible gas under its outer case, is at the mercy of an aeroplane that once gets above it. But in this instance the aviator was flying high when he sighted the Zeppelin, otherwise his machine could not have climbed to the superior height. The episode is well worth recalling here.

Warneford and another airman sighted the Zeppelin flying along the Belgian coast. As soon as the latter's crew observed the approach of the airmen, both of whom were handling quick-climbing Morane monoplanes, they rose rapidly, and turned for refuge to the aircraft gun defences of Ghent. This manœuvre was accompanied by rifle and machine-gun fire in which neither side appeared to score any advantage. Nearing Ghent, the airship began to descend, and Lieutenant Warneford seized his opportunity to get over his quarry. Then, swooping down, he dropped on it in quick succession the six bombs which he carried. Almost immediately it was seen that he had struck his mark, for the dirigible was quickly alight and appeared to explode, falling like a great fire ball on to a convent, which it partly destroyed, killing two of the inmates.

Meanwhile the force of the explosion so entirely upset the equilibrium of Warneford's aeroplane that it turned completely over, and only by the greatest presence of mind and consummate skill did the pilot recover his balance. But his engine had stopped, and he had to descend in the enemy's lines. The engine had stopped through one of the petrol tanks running dry. Bringing his second tank into use, he contrived unassisted to restart his engine and to escape back to his own lines to report his success.

On the following day the Admiralty announced that His Majesty had conferred the Victoria Cross on Lieutenant Warneford, and still later, the French President decorated him with the Legion of Honour.

The Zeppelin's height limit was then about 12,000 feet, and to attain that height something had to be sacrificed in the way of load and of duration capacity. It could climb the first 4000 feet in about three minutes, after which the rate of ascent was less. A fully loaded aeroplane of the period could not climb so well.

It seems inevitable, however, that the aeroplane will develop to a position of absolute superiority to the airship for fighting purposes. Carrying machine guns it will, at the same time, have greater speed and climbing power than any contemporaneous airship, and it will present a smaller target, particularly as to vital spots. The airship, it should be remembered, has only to catch fire in the air to suffer defeat, usually disastrous. By night, however, aircraft will always have a difficulty in finding each other, and reliance for defence will be chiefly upon anti-aircraft guns which will at least compel the enemy to keep at a high level.

THE DEVELOPMENT OF THE MILITARY AEROPLANE

The key herewith gives the position in the large plate of the various numbers.

No. 1.—A Maurice Farman biplane with 70 h.p. Renault engine. The first aeroplane to be used on active service by power, and was employed by the Italians in Tripoli, against Turks, for scouting, and for the dropping of bombs.

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No. 2.—The Nieuport two-seater monoplane employed in the same campaign, generally fitted with an 80 h.p. Gnome. The principal work of this and the preceding machine was scouting, but a little bomb-dropping was also done.

No. 3.—The 80 h.p. Blériot "tandem" two-seater. Used by the Bulgarians against the Turks.

No. 4.—A Deperdussin monoplane, used by the Turks in the Balkans wars.

No. 5.—The Henri Farman biplane, 80 h.p. Gnome. Used by the Serbians.

No. 6.—A D.F.W. biplane. The Turks used these steel-built biplanes, supplied by Germany, to a limited extent. These machines possessed a large measure of inherent stability, but their climbing power was limited. Usually driven by 100 h.p. Mercédès engines.

No. 7.—An Ago biplane, as supplied by Germany to Turkey.

No. 8.—A Rumpler-Etrich Taube, 120 h.p. Austrian-Daimler engine.

No. 9.—An early L.V.G. biplane, 100 h.p. Mercédès engine, used by the Germans in the early part of the Great War. Its elaborate chassis made it easy to land in bad ground, and it was quite a good all-round machine.

No. 10.—A B.E. 2b biplane, a product of the Royal Aircraft Factory, resembling the B.E. 2, and preceding the B.E. 2c. A large amount of reconnaissance was done on this type chiefly before and during the retreat from Mons.

No. 11.—A Morane "Parasol" monoplane. Notable for its wide field of vision and its rapid climb. It is, however, very tricky to handle when near the ground. This machine is usually fitted with an 80 h.p. Le Rhone motor.

No. 12.—A Bristol "Scout" biplane, a machine which did a vast amount of war flying. Fitted with a 100 h.p. monosoupape Gnome, one of the fastest machines of its type in the world; and its landing speed is low.

No. 13.—A German three-seater "battle-aeroplane," a powerful tractor biplane, which has done execution in aerial fights. Fitted with machine guns firing both fore and aft.

No. 14.—A Henri Farman version of the Voisin, a steel biplane fitted with a Salmson engine.

No. 15.—A standard straight-winged Aviatik biplane used largely for reconnaissance by the Germans. With the L.V.G. and Albatros it shared most of the German air-work.

No. 16.—A modern Albatros biplane. Note the claw-brake in the chassis. This enabled the machine to make a standing start with the engine running hard, without external assistance, the brake being released by the pilot from his seat.

No. 17.—A German two-fuselage, double-engined biplane which was not a success.

No. 18.—The Martinsyde single-seater scout biplane.

No. 19.—Vickers gun-carrier, driven by the 100 h.p. Gnome, the first gun-carrier of the "pusher" division to be used largely by the R.F.C.

No. 20.—Blériot armoured monoplane.

No. 21.—A two-engined Caudron biplane for bombarding. One of the successes of the Allies.

No. 22.—Morane monoplane, with Hotchkiss gun firing through the propeller.

No. 23.—Voisin gun-carrier.

No. 24.—Eighty h.p. Avro biplane. A machine which proved its merit early in the war. Three of these machines made the famous raid on Friedrichshafen.

No. 25.—A Maurice Farman of what is known as the "shorthorn" type, extensively used by the Allies.

No. 26.—A Fokker biplane scout. The German reply to the British biplane scouts.

No. 27.—A Nieuport biplane scout with gun firing upward through the top plane. Essentially a "parasol" monoplane with a very small bottom plane, the chief purpose of which is to prevent pendulum instability.

No. 28.—A Taube, only used in the early months of the war.

No. 29.—A kite-balloon.

Many of the machines in the plate show either a Maltese cross, painted on German aircraft; or the concentric rings which, in red, white and blue, identified those of the Allies.

CHAPTER XIX

THE GREAT WAR: LATER DEVELOPMENTS

BEFORE reviewing some of the later developments in aerial fighting called forth by the Great War, some impressions of flights over the battle lines may be given. Mr. Ralph Pulitzer, the well-known American writer, in the course of an account of a flight in a twin fuselage biplane with a French pilot, after describing the "crazy quilt of the country-side" as it appears from above, wrote :—

"On and on we flew until finally I felt, instead of hearing, a violent rapping. Turning my head, I saw the pilot hammering with his right fist on the deck between our cockpits to attract my attention.

"He grinned amicably and opened his mouth wide. I could see he was shouting at me, but could not hear the faintest sound over the roar of the propellers. He pointed to the whiteness below us a little to the right. Then he wrote an imaginary word with his forefinger on the deck between us. I could not read it upside down.

"I opened my leather coat, and with the cold instantly biting into my chest hauled out my notebook and pencil and stretched them out to him. He shook his head and indicated that he could not take both hands away from steering, so I buttoned up my coat again in some perplexity.

"Then, without abruptness, with a certain sickening majesty, the aeroplane stood on its head, and shot down on to the surface of the white sea below us. As it swallowed us we began to spiral rapidly round as though we were tobogganing at top speed down a giant corkscrew.

"As we went on down through this white nothingness, I became very dizzy. The propellers had slowed way down, and I thought the engine had failed, and that we were either falling, falling 10,000 feet, or making a forced descent. But the pilot sat still back above me, so I did likewise. Suddenly we spiralled violently down through the bottom of the cloud into sight of the earth again. Instantaneously the engines broke into their old roar, and the aeroplane stopped pointing straight down, and assumed a steep slant. If anyone ever breathed a sigh of relief I did it then.

"I felt the rapping behind me. Looking round I saw the pilot pointing down at the earth ahead to our right and shouting quite silently at me. I shook my head. Then as we careened downward he stopped his motors, and in the sudden deafening silence he shouted out, 'The front.'

"Here, if my hopes had materialized, I should be able to give a most striking picture of a battle as seen from an aeroplane. But honesty compels me to say that anyone who wants to get a good clear view of the front had much better go there on the surface of the earth and not through the air.

"In the first place it takes quite a little time and trouble to discern the lines of opposing trenches even when you stand on a quiet observation post with a General painstakingly pointing and explaining just where they run. Here, though we were now only 1000 metres up, we were racing along the front at 130 kilometres an hour, and all my friend the pilot could do was to point here and there frantically. So among the maze of white lines I saw running below me through the hazy atmosphere, some which I took for trenches were undoubtedly roads, some which I took for roads were equally undoubtedly trenches, while only a very few could I unhesitatingly guarantee to have been trenches.

"In the next place the roar of the engine totally drowned out all the reports of the guns, and the explosions of the shells which are such a striking feature of the front.

"To make matters still more undramatic, there was no battle going on at the precise moment when we shot downward out of the clouds, but only a rather languid artillery exchange.

"Even a regulating aeroplane which was sailing round directly below us and about halfway down between us and the earth, was having an exceptionally peaceful time of it.

"We could plainly look down and see the red, white, and blue circles of France painted on the tops of its planes, but there were none of the customary woolly little white clouds of German shrapnel bursting round it.

"Furthermore the batteries right below it and us, whose fire it was correcting by wireless, were so cleverly concealed that they were quite invisible. The only signs of its being a front at all were the bursting shells from the French batteries. These little puffs of smoke in the hazy distance the pilot spotted unerringly, but he had a discouraging time pointing them out to my unaccustomed eyes as we raced along."

Officers of the Royal Flying Corps describe the barbed wire with which the grappled lines of the Allies and the Germans sought to protect themselves, as appearing like a long wavy belt of bluish smoke.

Seldom could human beings be distinguished, for troops did not move in mass, and scarcely ever by daylight, but some of the big advances, when trenches were stormed and hand-to-hand fighting took place, made memorable battle pictures; and these scenes were particularly poignant to aerial scouts, who could see acres of thickly strewn bodies, and could comprehend at a glance the terrible toll of modern death-dealing machinery.

After these big movements the lines often became inextricably mixed. Trenches were occupied by isolated bodies of men, and the Generals of both sides found great difficulty in ascertaining the true position of affairs. Flying over the battlefield, aerial observers sketched the positions, and in many cases were able to say at once which trenches were occupied and whether they contained friends or foes. Great experience was required for such delicate observations, and here the capabilities of flyers were very various. One or two seemed to have special gifts. A case in point is that of a son of a well-known artist, who after the battle of Neuve Chapelle, when the trenches were in complete confusion, made observations from a height of over 8000 feet, and returned with a detailed report indicating which trenches were occupied and by whom. The report proved accurate in almost every detail.

Weather was seldom bad enough to prevent work in the air. Thus on December 9, 1915, a British aeroplane squadron bombed Miraumont during a gale of wind blowing sixty miles per hour. In the naval action off the German coast at the end of March, 1916, the part played by the aeroplanes is described by an eye-witness as follows :—

" The weather quickly grew worse, and just as the show was about to begin a terrific gale sprang up. Battle-cruisers, destroyers, and other craft were tossed about like corks. The wind was blowing fearfully and more than once we were in such a plight that many of us yelled, 'Good-bye, England, home and beauty.' To make matters worse, a terrific snowstorm came on, and the North Sea seemed to undergo a complete transformation. Nothing looked more unlikely than a battle in such weather conditions.

"But there was to be a scrap after all. For a while we strolled about off the German coast. Then we got tired of waiting, so we 'knocked at the door' to ask a question of the German Fleet. To while away the hours we put on a gramophone record, which blurted out, 'Here we are, here we are, here we are again!' But still there was no response. 'They can't be at home,' said a wag, 'let's have a peep round.' And we did.

"The moment was hardly opportune to carry out the seaplane raid, already deferred on account of the weather. The conditions, however, did not improve, and it was decided to let loose our flying men immediately. Five went up, young Lieutenant Reid leading. I shall never forget the scene as they soared amongst the snow-clouds right over Schleswig-Holstein, the shrapnel from the German anti-aircraft guns bursting against a background of snow with our airmen playing all kinds of tricks to dodge the fire.

"The German aviators came over in advance to meet us, and our gunners quickly set to work on them. They exploded shell after shell about the aeroplanes, and two at least, badly hit, promptly retired."

Early in the war darts were dropped with some effect from aeroplanes, but experience afterwards showed that the damage they did was not so great as could be done by other means. The darts consisted of two parts, a head and a short flanged shaft. The head measured 5·7 cm. (about 2¼ inches), the total length of the dart was 11·17 cm. (about 4½ inches). Both the head and flanged shaft were constructed of steel, the flange being formed of two flat pieces of metal set at right angles, the ends of the four flanges thus produced being let into the steel head. The diameter of the head was 8·5 mm. (about $\frac{5}{16}$ inch), tapering to a fine point. The weight of the whole dart was 320·8 grains.

In the Feldaerztliche Beilage of the *Muenchener* *medizinische Wochenschrift*, Dr. J. Volkmann, writing on the surgical experiences of the war, narrates that soldiers were resting at five in the afternoon of September 1, 1914, three companies bivouacking at an interval of about eight paces, whilst two aeroplanes were circling overhead at a height of about 1200 to 1500 metres. Suddenly one of the soldiers felt a stabbing pain in the right foot just above the heel. At first he thought he had been pricked inadvertently by one of his fellows, but this illusion was quickly dispelled when he heard cries of pain all around him. The horses, too, became restive, and two were subsequently found to be wounded. Looking at his foot the soldier found an iron arrow which had penetrated to a depth of 1½ cm. He plucked it out at once. About fifteen of his comrades were also hit, and one of them was pinned to the ground by a dart which had passed through one foot. The darts were dropped in bundles, and they scattered while falling.

In the reports of the fighting written by an official "Eye-witness" the difference between tactical and strategical aerial reconnaissance was explained, and it was recorded that observers usually excelled in one or another, not in both. Some observers appeared to have a natural gift for strategical reconnaissance, and were able to read with surprising quickness the import of movements seen on the black railway lines and the white roads of the expanse of country, sometimes from sixty to hundred square miles in extent, spread out below.

The wear and tear of men and machines on active service is serious. It may be stated as a general rule that an aeroplane pilot is worn out by three months of war flying, and that he must then have a long rest. There are exceptions, of course. But the need for frequent reliefs, and the casualties result in the necessity of a provision of 1000 pilots annually to maintain a force of 100 in the field. When it is considered that soon after war broke out the British pilots on Service numbered some hundreds the extent of the organization will be grasped. Machines wear out very quickly under the continual exposure to weather, rough landings, and gun-fire.

In the spring of 1916 the aerial raids by the Allies on enemy railways and depots became numerous and extensive. The bomb-dropping aeroplanes, usually carrying about 200 or 250 lbs. of bombs each, were escorted by battle aeroplanes equipped for the purpose of tackling enemy aircraft. In several raids upwards of fifty machines were engaged. The significance of this kind of warfare is obvious. As F. W. Lanchester says[1] :—

"Were our aircraft of sufficient numerical strength, it would no longer be a matter of individual and isolated raids on selected places at which the maximum of injury could be inflicted, but rather a continuous and unrelenting attack on each and every point of strategic importance. Depots of every kind in the rear of the enemy's lines would cease to exist; rolling stock and mechanical transport would be destroyed; no bridge would be allowed to stand for twenty-four hours; railway junctions would be subject to continuous bombardment, and the line of railway and roads themselves broken up daily by giant bombs to such an extent as to baffle all attempts to maintain or restore communication."

Reference is made in another chapter to the kite-balloon. Great Britain made extensive use of kite-balloons on ships, and good work was done by this means in the bombardment of the forts in the Dardanelles, the fire of British warships being directed by observers in kite-balloons sent up from ships' decks. Similar work was done on the Belgian coast and elsewhere.

The Great War threw light on the great question as to the utility of the dirigible balloon. Germany used Zeppelins with some success in reconnaissance at sea, but with it will not survive the

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[1] "Aircraft in War." By F. W. Lanchester.

The Develo

No. 1.—A tractor biplar fitted with pontoons. Uns

No. 2.—The first Curtiss to fly off water. Its first f

No. 3.—The Fabre mon in Europe.

No. 4.—The Gnosspelius plane with which experi flights were made with this

No. 5.—The twin-float tr used for experiments at Schwann, R.N. This mach twin-float tractor seaplanes

No. 6.—The Voisin " can an amphibian, having wheels

No. 7.—A twin-float Short

No. 8.—A single-float Sho floats came into operation a travelling on the water, and was discarded, as it made it at low speeds.

No. 9.—A single-float Cu machines were sold to the Ru much service.

No. 10.—A Curtiss

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No. 13.—The Sopwith "bat-boat." It was awarded a prize offered by A. Mortimer Singer for the first all-British machine to make a series of starts and alightings alternately on land and water.

No. 14.—An Albatros "Taube" monoplane. This machine beat all competitors in the Italian waterplane competition, but it never distinguished itself as a seaplane.

No. 15.—The 200 h.p. Salmson Bréguet.

No. 16.—The Sopwith tractor biplane fitted with Green engine on which Hawker made his attempt to win the £5000 prize for a seaplane flight round England.

No. 17.—A Caudron biplane with wheels let into the centre of the floats, offering the minimum of resistance in the air.

No. 18.—The Nieuport monoplane. This machine, built with a perfectly rigid chassis, has done much flying, particularly on service with the French navy.

No. 19.—A Blériot water-monoplane, so constructed that it could be readily converted into a land machine by removing the floats and fitting wheels.

No. 20.—A small Morane monoplane on which Garros did much flying in the Monaco Meeting of 1913.

No. 21.—A Sopwith "tabloid" seaplane with 100 h.p. monosoupape Gnome. On this machine Pixton won the "Schneider Cup" at Monaco in 1914, when he defeated the leading French aviators.

No. 22.—The Sopwith "pusher" biplane, adopted largely by the Greek navy.

No. 23.—The 160 h.p. Short biplane to seat four, on which Messrs. Horace Short, Alec Ogilvie, and Frank McClean made a journey up the Nile to Khartoum.

No. 24.—The Short tractor biplane with folding wings which can be opened and closed from the passenger's seat. These machines are particularly useful for work with a fleet, as five of them can be stowed in a space occupied by one with its wings extended.

No. 25.—The Zeppelin amphibian, built by the Friedrichshafen Aeroplane Company, a branch of the Zeppelin Airship Company. This machine attained considerable success in the German Lakes competition.

No. 26.—The standard 100 h.p. Gnome Henri Farman.

No. 27.—The Brandenburg tractor biplane, a standard seaplane on conventional German lines.

No. 28.—The Short "pusher" biplane, 160 h.p. Gnome, which appeared at the Naval Review during the month preceding the outbreak of hostilities. The first machine to be fitted with anything like a heavy gun, namely, a 1½-pounder.

No. 29.—The twin-engined Curtiss flying-boat "America." This machine was designed for an attempt on a flight across

CHAPTER XX

FLYING DEVELOPMENTS IN SIGHT

IT will serve no useful purpose to indulge in mere speculations as to flight possibilities. Everyone is familiar with the agreeable prophet who adopts the attitude of mind which refuses to see a limit to progress in any direction, and believes that everything man has imagined will someday come to pass; that because Jules Verne wrote a tale in which men are depicted making an enormous cannon and firing a bullet-house containing men to the moon and back, this will one day be accomplished. There is no room in this book for speculations far less adventurous than that; indeed, there is no room for mere speculations at all, and the present chapter will merely deal with developments of aerial navigation that, so far as the mechanical side goes, are clearly in view.

Many calculations have been made by mathematicians as to the ultimate possible development of the aeroplane in the matter of size. They, of course, merely indicate the possibilities and limitations in sight, taking into account existing factors, namely, the present state of development of the internal-combustion engine, and methods of construction at present extant.

We know enough, it is presumed, of aero-dynamics to be able to say that further progress may yet be possible in minor details, but that certain limitations can be foreseen. Solid practical progress is the result of the past few years' researches, and in the nature of things it seems that further progress will be slower in the future than it has been during the period when there was everything to learn.

Many of the leading theorists hold the opinion that the limit of aeroplane possibilities at present in view is summed up in a useful lift of about five tons. But to carry a burden of five tons it would be necessary to have engines developing some 2200 h.p., and from the commercial point of view the cost would make such a machine impracticable. For military machines, of course, cost is but little regarded.

The limiting factor in construction is that every slight increase in the span of the wings involves a disproportionate increase of strain, calling for increased weight of material. Mr. Lanchester put forward the theory that the weight of the wings must increase as the cube of the span. That is to say, if a machine 40 feet in span has wings weighing 300 lbs., the wings of an 80-foot machine must weigh 2400 lbs. to give the same structural strength. This view, however, is by no means accepted by all authorities, some of whom maintain that the adoption of the twin-fuselage method secures the possibility of increase of span with weight in practically direct proportion thereto. Mr. Lanchester came to the conclusion that, all things considered, a useful load of considerably less than a ton is the limit. Other authorities, as already said, think it possible to attain to four or five tons with a reasonable factor of safety, and that British War Office requirements in the latter respect—on which Lanchester's calculation is based—are capable of considerable modification without endangering the safety of the machine.

By the end of 1915 aeroplanes weighing "all on" about ten tons, having a useful lift of about three tons, driven some by three, some by four, some by five engines, the total engine power being in the neighbourhood of 1200 h.p., were being made for use over sea or land. A Curtiss air boat of fifteen tons (useful lift about five tons) was under construction, its wings with a span of 135 feet and one of its cabins measuring 19 feet by 8 feet. The power to fly this huge vehicle was derived from four motors each of 250 h.p.

Enthusiasts need feel no disappointment with the limit set to the size of the coming aeroplane. If the limit should prove to be only three tons useful lift such machines would be capable of remarkable performances and would have an industrial and also a military significance of revolutionary importance.

Non-technical readers, perhaps, have no conception of the vast work involved in designing each new aeroplane development. Actually, a new aeroplane, not counting the engine, not necessarily a radical departure from previous types, requires anything from 150 to 250 working drawings and a vast amount of calculations.

Looking ahead in the light of actual experience and not indulging in fancies, it can be clearly seen that the employment of large forces of big aeroplanes capable of starting from England and in a few hours bombarding cities on the far side of the Rhine will be possible. In like manner, a hostile European Power with bases near the North Sea could attack our inland towns and our railway lines and depots.

National defence must therefore take on a new aspect. To resist attack, it is true, established military methods must be used, but the material will be different; the guns will be different; different projectiles will be used; and attack and counter-attack will often be by aircraft which, navigating the air, are entirely differently environed and conditioned from vehicles ordinarily used by the Navy and Army.

New strategical considerations arise, demanding special study, special training, and highly technical knowledge. War in future will begin with sudden and unannounced raids on a large scale on the enemy's railway systems. And armament for offence and methods of defence only dimly foreshadowed during the Great War will be demanded. Bomb-dropping from aircraft calls for different training from that of any artillery, and in many cases the projectiles are different.

Further, navigation of the air goes hand in hand with ocean navigation only a very short distance; it then calls for knowledge and training of a kind foreign to seamen. The study of the atmosphere itself is the study of a lifetime, and will require highly specialized attention.

Apart from military value the future of the aeroplane is a matter of intense interest. Has it a commercial future? To answer that question it will be well to resist the temptation to assume very much cheaper machines and cheaper fuel than those in use. A quite reasonable calculation that appeared in a technical journal is here quoted:—

"Take, for example, an aeroplane of 1000 h.p. Allowing a carrying capacity of 20 lbs. per h.p.—which represents fairly high efficiency, but is permissible because big aeroplanes should be more efficient than small ones—we have a lifting capacity of 20,000 lbs. The machine and engine may weigh about 8000 lbs., leaving a useful load of 12,000 lbs.

"Allowing one hour's petrol for 1000 h.p. at 0·7 pint per h.p. hour, we get 87 gallons per hour, or 435 gallons for five hours, which will weigh 3130 lbs. Oil for five hours would weigh about 313 lbs. Thus the total weight of fuel should be 3443 lbs.

"Deducting this from the 12,000 lbs. useful load, we find 8500 lbs. available for forty-two paassengers at 200 lbs. each—including light baggage—or twenty passengers and about 4000 and odd lbs. of mails or heavier baggage.

"Now, the machine should have a speed of between eighty and ninety miles an hour, so we may assume that it is ready at any time for a non-stop journey of 300 miles in the five hours, even against a moderately strong head wind.

"The cost of 435 gallons of petrol, at the top price of

1s. 6d. per gallon, is £33, and the oil should cost about £12, so the total fuel cost should be inside £50 per journey.

"The rest of the running costs would depend on the price of the machine—which ought to be somewhere in the region of £10,000—on the number of trips it could do per annum, and the number of trips it could do without any serious mishap. One may assume that with powerful and reliable engines the chances of mishap would be small, as nearly all accidents are caused either by engine failure at awkward moments, or by pilots trying to do something of which they are incapable. On the whole one might take it that with proper, careful handling the aeroplane should last till general wear and tear necessitated rebuilding.

"On this basis, running costs, other than fuel, may be estimated on the capital involved in the machine, the housing, and in general running expenses, which should be only slightly higher than those of a garage running motor-buses or motor-cars to a similar capital value."[1]

It need only be remarked that although open here and there to technical contention the estimate is sufficiently within the mark to serve as a guide.

But it may confidently be expected that an increase of private flying and of commercial enterprise will be seen, and that the formation of flying clubs and rapid improvement in flying facilities that must take place will lead to increased production, to standardization, and therefore to reduced cost. It will be the care of enlightened Governments to encourage this development by all reasonable means. In February, 1916, the United States Post Office Department advertised for proposals for carrying mails by aeroplane. Eight routes were indicated, and maximum loads up to 3000 lbs. of mail in some cases specified. The distances varied from 52 to 380 miles.

Airship development is referred to in Chapter XIII, and it need only be remarked that it is conceivable that a non-inflammable gas of approximately the same specific gravity as hydrogen, and no more difficult to procure, will some day be available. Another important direction of improvement lies in the maintenance of an even temperature of the gas in a balloon, which would greatly prolong the duration of a voyage. If effected to a very marked degree it would to some extent counter-balance the expansion and contraction of the gas under different atmospheric pressure. But what this would mean may be indicated by the fact that a rise or fall of 18 or 20 degrees would be necessary to have the same effect as a rise or fall of 1000 feet of altitude.

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[1] *The Aeroplane*, 29 December, 1915.

In 1913–14 there was a movement in France aiming at the development of a flying machine that could take the air with the aid of one man's muscular power. Various contrivances of wing and plane were tried, many of them being based upon the bicycle principle, the pedalling action being employed to get speed up on the ground and to drive a propeller. No success was achieved, and it may be said that no success will be attained on these lines unless some improved method of converting muscular energy, or else some much superior plane-design to any yet known be discovered.

Blériot's experiments in 1913 with an aeroplane designed to fly from and alight upon a cable-way appears to indicate an important new type capable of rendering unique service even though the hydro-aeroplane should overcome the troubles and disabilities under which it has laboured. If the cable plane or deck-plane should be a success, it would not only be able to co-operate with warships far away from land but, what is even more important, it would aero-dynamically be more efficient than any existing aeroplane or seaplane. It would need no wheeled landing carriage, nor the still more impeding float or boat. And this would secure a great gain in flying efficiency. The wings would be made unsinkable for emergency descents into the water ; but usually the deck-plane would use its cable. Liners and mail boats could carry this contrivance, so that increased mail facilities are foreshadowed. And there appears to be no reason why such a craft should not be used overland, although it would require suitably equipped stations. Less power would be needed to launch the deck-plane into flight than is required by machines that must get up speed on ground or water. This means economy in power. In the early days the Wright aeroplane took flight off a rail launching apparatus, and on this account it was able to use comparatively small engine power.

Towards the end of 1908 it was recognized that the conquest of the air involved the need for establishing an entirely new set of laws covering international, State, and private interests. The French Government decided to summon an International Conference "to consider the question of the introduction of a code of laws on aerial navigation" ; and it was high time, for the legal problems of aerial flight began to threaten trouble. Questions of frontiers arose, as in the complaints of German balloons crossing into France, delicate matters of espionage and smuggling, and the obvious charge of trespass was one that could not long escape coming before the law-courts in different countries. At present there are no statutes in existence defining the rights either of aeronauts or of the citizens upon whose property and comfort they may be thought to have encroached.

On January 11, 1908, an International Aeronautical Conference was held in London by the Federation of Aero Clubs, and a Commission was appointed to discuss the legal rights of aeronauts. Wireless telegraphy had already drawn attention to national rights in the atmosphere, and in approaching the subject of aerial locomotion closely one's mind naturally sought for a parallel in the conditions which rule maritime affairs.

The seas are free to all, with the exception of a narrow shore-strip of three miles, and certain established fishing proprietaries. Why should not the air be equally free? As a matter of fact, there is no real parallel between the sea and the atmosphere in this respect. The sea meets the land at the coast-line; the air covers land as well as sea. From the air every square foot of a nation's territory is "frontier." All towns and villages are potential ports of entry. Every acre, therefore, may require Custom House, passport officers, and guards.

It is not likely that flying at a reasonable height—sufficient to avoid annoyance—over private property will be prohibited, and it appears probable that the only danger to the freedom of the air will be from State interference on the grounds of military security.

In March, 1913, the British Government issued a drastic series of regulations for the purpose of preventing the entry into Great Britain of aircraft from abroad except upon certain definite conditions. These regulations applied to all aircraft, whether dirigibles or aeroplanes, whether British or foreign owned, whether the property of private individuals or of Governments other than our own. But whereas privately-owned craft could enter the country within certain specified landing areas, if those in charge gave due notice—forty-eight hours in the case of airships, to the nearest Consular officer to the point of departure, and eighteen hours by wire or letter to the Home Office in the case of aeroplanes—foreign naval or military aircraft were absolutely prohibited from landing on British soil except upon the "express invitation or express permission" of His Majesty's Government.

No entry might take place except within the areas enumerated in the schedules, and none at all at a very large number of points, the names of which were set out in the rules.

Before an aircraft was allowed to come over, the fullest details of the ship, her crew and passengers, destination, object, etc., had to be furnished: when she arrived she was obliged to pay a fee of £3 for an airship, and £1 for an aeroplane; and when she was about to quit the United Kingdom she had to descend in one of the permitted areas and report herself.

Infringement of the regulations rendered the offender liable to penalties of six months' imprisonment or £200 fine, or both, and the Act passed in February, 1913, also provided that if the aeronauts omitted to descend when signalled to do so, according to the code of signals provided for the purpose, they might be fired on by orders of a duly authorized officer. Moreover, under certain circumstances, as was pointed out, offenders might come under the Official Secrets Act, and be liable to seven years' penal servitude.

Flying over certain areas of military importance was entirely prohibited to aircraft, British or foreign, and flying over towns and any large assembly of people was also forbidden.

One use for aircraft may, in conclusion, be indicated. Many regions of the globe still remain to be explored, and aerial navigation should supply the easiest means of access to some of them. There is a huge region in south-eastern Arabia, some 400,000 square miles, the "Dwelling of the Void." Then there are Tibet and extensive regions of the Himalayas. New Guinea offers another field, and there are regions in Africa closed at present to the ken of our civilization. In South America, in Bolivia, and in Central Brazil there are some 2,000,000 square miles of unexplored land. How much more is there of the unknown ocean, not less important than the land to the geographer? But the secrets of all these places are to be laid bare, and aerial navigation is destined to supply the key to many of them. Various schemes for the aerial exploration of some of these regions have been mooted.

APPENDIX

PRINCIPAL WORLD RECORDS, 1916—AVIATION

(*m.* =Monoplane ; *b.* =Biplane)

The following are the principal world records selected from th recognised by the Fédération Aéronautique Internationale. S interesting records are not recognised, or have not yet been by the F.A.I., and these are indicated by an asterisk. recognised by the Royal Aero Club, but not by the F.A.I., indicated by a dagger.†*

So greatly have the motor-power and general capabilities aeroplanes been increased during the war that it is highly prob that many of the following records have been surpassed.

SPEED

5 kilometres.—1 min. 43·4 sec., J. Védrines, in U.S.A., Sept. 9th, 1912 (Deperdussin *m.*, 160 h.p. Gnome motor).

SPEED OVER CLOSED CIRCUIT

126·67 miles per hour.—M. Prévost, in France, on Sept. 29 1913 (Deperdussin *m.*, 160 h.p. Gnome motor).

DISTANCE IN CLOSED CIRCUIT WITHOUT ALIGHTING

Pilot alone

646 miles.—A. Séguin, Paris-Bordeaux-Paris, Oct. 13th, 19 (H. Farman *b.*, 80 h.p. Gnome motor).

DURATION

*24 hrs. 12 min.—R. Boehm, at Johannisthal, on July 10–11 1914 (Albatros *b.*, 75 h.p. Mercédès motor).

21 hrs. 48 min. 45 sec.—W. Landmann, in Germany, on J 26–27th, 1914 (Albatros *b.*, 75 h.p. Mércedès motor).

ALTITUDE

Pilot alone

*25,756 feet.—Oelrich, in Germany, on July 14th, 19 *b.*, 120 h.p. Beardmore-Austro-Daimler motor).

21,456 feet.—E. Audemars, at Issy, on Sept. 8th,

Pilot with one Passenger

42 feet.—H. Bier, in Austria, on June 27th, 1914 (Al-
b.).

Pilot with two Passengers

47 feet.—H. Bier, in Austria, on June 28th, 1914 (Al-
b.).

SLOW FLIGHT

4 miles per hour. A. Ogilvie, at Lanark, August, 1910
t *b.* and motor).

OVERSEA

miles.—Lieut. Gran, from Cruden Bay, Aberdeenshire,
ppe, near Stavanger, in Norway, July 30th, 1914 (Blériot

CROSS-COUNTRY (NON-STOP)

5 miles.—A. Séguin, Paris-Bordeaux-Paris, Oct. 13th, 1913
rman *b.*, 80 h.p. Gnome motor).

BRITISH RECORDS†

DURATION

rs. 23 min.—H. G. Hawker, at Brooklands, on Oct. 24th,
(Sopwith *b.*, 40 h.p. A.B.C. motor).

ALTITUDE

Pilot alone

393 feet.—H. G. Hawker, at Hendon, on June 6th, 1915
ith *b.*, 80 h.p. Gnome motor).
,900 feet.—Lieut. Norman Spratt, at Brooklands, on March
1914 (R.E. *b.*, 120 h.p. Beardmore-Austro-Daimler motor).

CROSS-COUNTRY (NON-STOP)

o miles.—Capt. Longcroft, with passenger, Montrose to
mouth and back to Farnborough, on Nov. 24th, 1913
b., 70 h.p. Renault motor) (not in Royal Aero Club list).

RECORDS—DIRIGIBLE BALLOONS

ALTITUDE

Conté (French-Astra non-rigid), 3,080 metres (10,105 ft.),
y, June 18th, 1912.
(Zeppelin), 10,256 feet, at Friedrichshafen (with 17
ngers), May 16th, 1914.
1 (Italy), 3,270 metres (10,728 ft.), Feb., 1915.

DISTANCE

The *P5* (Italy), 506 miles, on July 30th, 1913.

*The *M2* (Italy)—Wolseley motors—745 miles, on Oct. 1913. (Longer voyages on Zeppelin airships have, however, made.)

DURATION

The *P5* (Italy), 15 hours, on June 25th, 1913.

*The *Adjudant Reau* (France), 21 hr. 20 min. 50 sec., on 10th, 1911.

*The *Adjudant Vincenot* (France), 35 hr. 20 min., on 27th, 1914.

**L3* (Zeppelin), 34 hr. 59 min., on May 17th, 1914.

SPEED

The *P5* (Italy), 64,800 kiloms. per hour (40¼ miles per on July 30th, 1913.

*The *L2* and later Zeppelins on speed trials attained more 52 miles per hour; and it is claimed that the Italian *V* attained the speed of 58 miles per hour in official trials, 1915.

RECORDS—SPHERICAL BALLOONS

ALTITUDE

Süring and Berson, June 31st, 1901, at Berlin, 10,800 (34,433 ft.).

DURATION

Hugo Kaulen, Bitterfield to Perm, 87 hr., Dec. 13–17th,

DISTANCE

Berliner, Bitterfield to Bissertsk (Perm, Russia), 1,895 Feb. 8–10th, 1914.

†British Record.—A. E. Gaudron, with E. M. Maitland C. C. Turner, London to Mateki-Derevni, Russia, 1,117 Nov., 1908. (Duration record also—31½ hours.)

VOCABULARY OF AERONAUTICAL TERMS

ere will be found :

) A list of technical terms issued by the Aeronautical Society reat Britain.

) A number of aeronautical terms not included in that list.

) A list of French technical terms commonly found in books articles on aeronautics.

LIST I

OFOIL.—A structure, analogous to the wing or tail of a bird, designed to obtain a reaction from the air approximately at right angles to the direction of its motion.

SCREW.—Used as a generic term to include both a propeller and a tractor screw. See " Screw."

ERON.—See " Balancing Flap."

GHTING CARRIAGE.—See " Carriage."

LE, DIHEDRAL.—In geometry the angle between two planes. The wings of an aeroplane are said to be at a dihedral angle when both right and left wings are upwardly or downwardly inclined to a horizontal transverse line. The angle is measured by the inclination of each wing to the horizontal. If the inclination is upward the angle is said to be positive, if downward, negative.

LE, GLIDING.—The angle between the horizontal and the path along which an aeroplane, in ordinary flying attitude, but not under engine power, descends in still air.

LE OF INCIDENCE OR ANGLE OF ATTACK.—The angle a wing makes with the direction of its motion relative to the air. The angle is usually measured between the chord of the wing and the direction of motion.

ITUDE.—An aeroplane's or wing's position relative to the direction of motion through the air.

K, TO.—Of the wind, to change direction counter-sunwise (counter-clockwise).

ANCING FLAPS.—Aerofoils used for causing an of balancing. roll about its longitudinal axis for the purpose aeroplane to

BALLONNET.—A word taken from the French meaning "a l
balloon" and exclusively limited to an interior
containing air, within the envelope of an airship.

BANK, To.—To heel for the purpose of turning.

BODY.—Of an aeroplane—that part which usually contains
engine, crew, tanks, etc., and to which the wings, car
and other organs are attached.

BRACING.—A system of struts and ties to transfer a force f
one point to another.

CABANE.—A French word to denote the mast structure projec
above the body to which the top load wires of a monop
are attached.

CABRÉ.—Tail-down.

CAMBER (of a wing section).—The convexity of a wing sec
The camber is usually measured (as a fraction of
chord) by the maximum height above the chord.

CANT, To.—To tilt; to take any inclined position.

CARRIAGE.—That part of the aircraft beneath the body inte
for its support on land or water and to absorb the s
of alighting.

CHASSIS.—See "Carriage."

CHORD.—The straight line (taken conventionally fore and
unless otherwise specified) touching the under surface o
aerofoil at or near the leading and trailing edges.
length of the chord is the projected length of the sec
on the chord.

CLINOMETER.—See "Inclinometer."

CONTROL LEVER.—On an aeroplane, a lever by means of wh
the principal controls are worked. It usually cont
pitching and rolling.

CROSS SECTION (of an Aerofoil).—The section cut by a fore and
plane normal to the surface (commonly the under surfa

DIHEDRAL ANGLE.—See under "Angle."

DIVE.—To descend steeply with the nose of the aircraft dow

DOPE, To.—Of fabrics—to paint a fabric with a fluid subst
for the purpose of tightening and protecting it.

DRAG.—The resistance along the line of flight; the head
sistance. Compare "Drift."

DRIFT, To.—To be carried by a current of air or water; to m
leeway.

DRIFT.—The distance drifted. The speed of drifting. The w
"drift" having a well accepted nautical significa
should be avoided as far as possible in the sense of "h
resistance" or "drag."

LEVATOR.—An aerofoil set in a more or less horizontal plane and hinged on an athwartships or transverse line. It is used for controlling the angle of incidence of the aeroplane.

NTERING EDGE.—See "Leading Edge."

AIRING.—A piece added to any structure to reduce its head resistance or drag.

INS.—Subsidiary aerofoils set parallel to the normal direction of motion of an aircraft.

LAPS, BALANCING.—See under "Balancing."

LAPS, WING.—See under "Balancing."

USELAGE.—See under "Body."

AP.—The distance between the upper and lower wings of a biplane. For specific purposes the points between which it is measured should be indicated.

LIDE, TO.—To fly, usually on a descending path, when the aircraft is not under engine power.

LIDING ANGLE.—See under "Angle."

ICIDENCE, ANGLE OF.—See under "Angle."

ICLINOMETER.—An instrument for measuring the angle of slope of an aircraft, referred to the horizontal.

EADING EDGE.—Of a wing—the forward edge.

EEWARD.—Away from the wind.

EEWAY.—Lateral drift to leeward.

IFT.—The force exerted by the air on an aerofoil in a direction perpendicularly or nearly so to the motion. Usually upwards in ordinary flight.

ONGITUDINALS.—Of an aeroplane, the long fore and aft spars connecting the main with the subsidiary supporting or controlling surfaces.

ONGERON.—See "Longitudinal."

ANCAKE, TO.—To descend steeply, with the wings at a very large angle of incidence, like a parachute. Contrast "Dive."

ITCH, TO.—To plunge in the fore and aft direction (nose up or nose down). Contrast this with "Roll."

ITOT TUBE.—A tube with open end facing the wind, which, combined with a static pressure or suction tube, is used in conjunction with a gauge to measure fluid pressure or velocities.

Pressure Head.—A combination of pitot tube and static pressure or suction tube, which, in conjunction with a gauge, is used to measure fluid pressures or velocities.

Pressure Tube, Static.—A tube (usually with holes in its sides past which the fluid flows) so designed that the pressure inside it equals the pressure exerted by the fluid on any body at rest in the fluid. Used as part of a pressure head.

Propeller.—An air-screw behind the main supporting surfaces. Compare "Tractor."

Pylon.—A mast or post.

Rib.—Of a wing, a light fore and aft member which carries the fabric for the purpose of giving the desired cross section to the wing.

Rib, Compression.—A rib designed to act as a strut between front and rear spars of a wing.

Roll, To.—To turn about the fore and aft axis.

Rudder Post.—The main post of a rudder.

Rudder.—A subsidiary aerofoil (in an aeroplane more or less perpendicular to the main supporting surfaces) by means of which an aircraft is turned to right or left.

Rudder Bar.—The foot-bar, by means of which the rudder of an aeroplane is worked.

Screw, Air.—An aerofoil so shaped that its rotation about an axis produces a force along that axis for driving an aircraft.

Side Drift.—See "Drift."

Side Slip, To.—In an aircraft, to move more or less broadside on relatively to the air.

Skid.—A part of the alighting gear of an aircraft arranged to slide along the ground.

Span, of Wings.—The distance from wing tip to wing tip.

Span, of Aeroplanes.—The maximum transverse dimension.

Spar.—A long piece of timber or other material. In a wing, either of the beams which run transversely to the aircraft, and transfer the lift from the ribs to the frame and bracing.

Stagger.—Of wings. When the wings of a biplane are set with the upper one slightly ahead of, or abaft of the other, they are said to be staggered. The stagger is measured by the angle made by the line joining the leading edges with the normal to the fore and aft axis of the aeroplane. It is convenient to call the stagger positive if the upper wing is ahead of the lower.

Static Pressure Tube.—See under " Pressure."

Statoscope.—An instrument to detect the existence of a small rate of ascent or descent.

Strainer.—An appliance bearing a suitable mesh for straining impurities from petrol and other fluids. Also compare " turnbuckle."

Stream-line.—The path of a small portion of a fluid, supposed continuous, moving relatively to a solid body. The term is commonly used only of such paths as are not eddying, but the distinction should be made clear by the context.

Strut.—A structural member intended to resist compression in the direction of its length.

Tail.—The after part of an aircraft, usually carrying certain controlling organs.

Tie.—A structural member intended to resist tension.

Top Surface Camber.—See under " Camber."

Top Load Wires.—See under " Wires."

Top Warp Wires.—See under " Wires."

Tractor.—An air-screw mounted in front of the main supporting surfaces.

Tractor Machine.—An aeroplane with air-screw mounted in front of the main supporting surfaces.

Trailing Edge, of a Wing.—The after edge.

Turnbuckle.—A form of wire tightener.

Under-Carriage.—See " Carriage."

Under-Surface-Camber.—See " Camber."

Veer, of the Wind.—To change direction sunwise (clockwise).

Velocity of Sideslip.—The speed with which the craft moves broadside on with respect to the air. Distinguish from " drift," q.v.

Warp, To.—Of a wing, to bend so that the outer end of the back spar moves up or down. It is convenient to call the warp positive when the movement is downwards.

Wing Flaps.—See " Balancing Flaps."

Wings.—The main supporting organs of an aeroplane. A monoplane has two wings, a biplane four.

Wires, Lift.—Wires, the principal function of which is to transfer the lift of the wings to the body or other part of the aeroplane structure.

WIRES, WARP.—Lift wires connected to the back spar and controlled so as to move its outer end down for the purpose of warping the wing.

WIRES, TOP LOAD.—Wires intended mainly to resist forces in the opposite direction to the lift.

WIRES, TOP WARP.—Top load wires connected to the back spar and passing from wing to wing to allow the wings to warp.

WIRES, DRAG.—Wires, the principal function of which is to transfer the drag of the wings to the body or other part of the aeroplane structure. Wires intended mainly to resist forces in the opposite direction to the drag are sometimes called " anti-drag wires."

WIRES, DRIFT.—See " Wires, Drag."

WIRE-STRAINER.—See " Turnbuckle."

YAW, TO.—An aircraft is said to yaw when its fore and aft axis turns to right or left out of the line of flight. The angle between the fore and aft axis of the aircraft and the instantaneous line of flight.

LIST II

OTHER TERMS IN COMMON USE

AERODROME.—The ground from which flying experiments are made. F. W. Lanchester uses the word in its purely etymological meaning, and he calls a flying-machine an " aerodrome." But custom is against the use of the word in this sense. In like manner we call a place where horses practise a " hippodrome " ; we do not call a horse-drawn vehicle a " hippodrome."

AEROPLANE.—A flying apparatus with one or more planes or carrying surfaces.

AEROSTAT.—Balloons of any form, as distinct from heavier-than-air aerial machines.

AIRSHIP.—The term is usually confined to dirigible balloons.

AVIATION.—Flight, as distinct from ballooning.

AVIATOR.—The driver of a heavier-than-air flying apparatus.

BALLAST.—Any substance taken in a balloon to throw out for the purpose of lightening the load carried. Sand is usually employed as ballast.

Ballon-sonde.—A small balloon sent up with automatically-recording instruments, which, when the balloon bursts at a great altitude, come down attached to parachutes. By this means observations are taken of strata of the atmosphere to which human beings cannot ascend.

Biplane.—A flying apparatus with two main planes or "carrying surfaces" one over the other.

Buoyancy.—The property by which a balloon remains floating in the air. If the balloon has little buoyancy, it descends; if it has more buoyancy, it ascends.

Captive Balloon.—A balloon attached to ground by means of any cable.

Carburetter.—An apparatus by which the air is charged with carbon, or carbon and hydrogen, so that it will burn. That part of the motor in which petrol vapour becomes mixed with air in the proportion necessary for making the explosion.

Cross-tail.—A tail formed by intersecting vertical and horizontal planes.

Curtains.—Vertical planes between horizontal planes, thus forming the structure into a kind of box-kite.

Dirigible Balloon.—A balloon driven by a motor and steered.

Free Balloon.—A balloon that is not held by cables to the ground.

Floater.—Usually a hollow cylinder suspended by a rope from a balloon, and floating in the water for the purpose of keeping the balloon at uniform altitude; and also, by retarding the balloon's motion sufficiently to give it a certain amount of wind-pressure, to enable the aeronaut to put up a sail, and so slightly divert the course of the balloon.

Fusiform.—Spindle-shape.

Glider.—A machine that glides through the air. The term is used to denote an apparatus for gliding without a motor.

Gyroplane.—A flying-machine with rotating wings.

Heavier-than-air.—A term applied to all aerial vessels whose ascensional power is not derived from gas.

Helicopter.—A machine with propellers placed horizontally, so that their revolution gives the apparatus an upward motion. The propellers are usually capable of being tilted, in order to give the machine forward as well as upward motion.

HELIX.—The trace of a point moving uniformly round a cylinder, at the same time ascending at a uniform rate.

HORIZONTAL STABILITY.—See "Stability."

INCIDENCE, ANGLE OF.—Often defined as angle of chord to line of thrust.

INCLINATION.—The inclination of a plane is its angle to the horizontal.

KEEL.—A vertical plane or planes arranged longitudinally below or above the body of a flying-machine for the purpose of giving stability; also on some dirigible balloons.

KITE-BALLOON.—A form of captive balloon, with lifting-power derived partly from the buoyancy of its gas and partly from air-pressure, as in a kite.

LIFTING-POWER.—A balloon's capacity to lift itself in the air and to carry objects with it.

LIGHTER-THAN-AIR.—A term used to denote all aerial vessels whose ascensional power is derived from the buoyancy of gas or hot air.

MAGNETO.—That part of the motor which produces the electric sparks which, igniting the petrol vapour, make the explosions in the cylinder.

MOTOR.—Any engine—steam, electric, or petrol.

MONOPLANE.—A flying apparatus with one or more pairs of wings or "carrying surfaces" arranged in the same plane.

MONTGOLFIÈRES.—Balloons whose ascensional power is obtained from hot air.

MULTICELLULAR.—A structure consisting of a row or rows of compartments like box-kites.

NON-RIGID TYPE.—Used of dirigible balloons whose envelopes are not strengthened by any kind of framework; shape maintained solely by internal pressure.

ORNITHOPTER OR ORTHOPTER.—A flapping-wing machine.

PANEL.—Vertical planes dividing biplanes into cells.

PILOT BALLOON.—A small balloon sent up before an ascent, to see in which direction the air-currents are moving.

Pitch of Screw.—The length of a complete thread measured on the axis. The rise in one complete turn, or the distance through which it could advance in one complete revolution, provided it revolved in an unyielding medium such as a solid nut.

Radiator.—That attachment to the motor which cools the water after leaving the cylinders. In some of the lighter forms of motor the cooling is effected by a rush of air, sometimes provided by a revolving fan.

Rigid (airship).—The gas-container being enclosed in a metal or other stiff case, as in the Zeppelin. No interior pressure required.

Ripping Panel.—A long seam in the upper part of a balloon, which can readily be torn open by the aeronaut, thus quickly deflating the balloon in descending.

Semi-rigid type.—The gas-container of fabric resting on a metal or other rigid keel, or containing an interior skeleton, giving a certain amount of rigidity.

Slip.—The difference between the forward movement of the propellers if they were in a solid (as a bolt screws into a nut) and the actual forward motion of the air-craft driven by the propeller.

Stabilizer.—The tail of a flying-machine.

Stability.—The maintenance of even flight. Absence of rolling and pitching.

Lateral stability is the absence of wobbling or canting from side to side.

Longitudinal stability is the absence of pitching motion forward or backward in the line of flight.

Weathercock stability is the absence of yawing.

Superimposed or Superposed.—Placed one over the other.

Sustainers.—The main planes in a flying-machine. All plane surfaces whose purpose is not for steering, but which provide the lifting-power of the machine.

Trail-rope.—A rope hanging from a balloon, and trailing along the ground, assisting the balloon in keeping uniform altitude.

Triplane.—A flying apparatus with three main planes one over the other.

Aeronat.
Aeronef.
Ailerons.
Ailes.
Allumage.
Amiante.
Appendice sustentale.
Arbre d'hélice.
Arbre secondaire.
Avance à l'allumage.
Axe.
Balai.
Batterie.
Béquille.
Bielle.
Biplan.
Bougie.
Boulon.
Boussole.
Burette.
Cabillot.
Cable.
Cabré.
Came.
Carter

Cloisonne.	A term descriptive of machine of the cellular type.
Compasses.	Compasses.
Coup.	Knock.
Cramponner.	Clamp.
Cric.	Jack.
Cross-béquille d'arrière.	Rear support.
Démultiplicateur.	Mechanism for gearing down from motor to propeller.
Dérates.	Missing.
Direction.	Foot lever.
Échappement.	Exhaust.
Écrou.	Bolt.
Écrou à creiller.	Finger-nut.
Embrayage.	Clutch.
Emerillon.	Strainer.
Emery toile.	Emery cloth.
Empennage.	The stability planes arranged about the tail of a dirigible; also the feather-tail of an arrow.
Entonoire.	Funnel.
Essence.	Petrol, spirit.
Essieu.	Axle.
Etaux.	Vice.
Forest.	Hand drill.
Freins.	Brakes.
Fuselage.	Fusiform frame.
Goupille.	Split pin.
Gouvernail.	Rudder, lever.
Graisse.	Grease.
Guignol.	Rudder.
Hangar.	An aeroplane garage.
Hélice.	Screw propeller.
Isolant.	Insulator.
Jauge.	Gauge.
Lier.	To tie,
Lime.	File.
Manche à air.	Air-feeder.
Manivelle.	Crank.
Manomètre.	Pressure meter.
Marteau.	Hammer.
Montant.	Strut.
Nacelle.	The basket or car of a balloon
Panneau de déchirure.	Ripping panel.
Patin.	Skid.
Pince-platte.	Pliers.
,, rond.	
,, coupante.	

Pignon.	Cog.
Pignons coniques.	Bevel wheels.
Pile.	Battery.
Plan.	Plane.
Pneu.	Tyre.
Poche à air.	Air pocket.
Poignée.	Handle.
Pompe.	Pump.
Pompe d'alimentation.	Feed-pump.
Poste du pilote.	Aeronaut's position.
Ralingue.	Bolt-rope.
Régulateur.	Governor.
Réservoir d'essense.	Petrol tank.
Ressor.	Spring.
Retard à l'échappement.	Exhaust-valve regulator.
Robinet de compression.	Compression-tap.
Roue.	Wheel.
Scie.	Saw.
Soupape à gaz.	Gas-valve.
Soupape automatique.	Automatic valve.
Soupape d'admission.	Induction valve.
Soupape d'échappement.	Exhaust valve.
Tendeur.	Wire stay.
Tige de connection.	Connecting-rod.
Tireveille.	Rudder line.
Tourne vis.	Screw-driver.
Trembleur.	Contact breaker.
Valve d'arrêt.	Check valve.
Vis.	Screw.
Volant de direction.	Steering-wheel.
Volante.	Fly-wheel.
Volet de déchirure.	Ripping panel.

LIFT AND "DRAG"

From the following table, which is extracted from Chanute's more complete one, it will be seen in what proportion the "lift and drag" of an inclined plane increase with increasing tilt.

Angle of Inclination. Degrees.	Normal Pressure.	Lift.	Drag.
2	0·070	0·070	0·0024
4	0·139	0·139	0·0097
6	0·207	0·206	0·0217
8	0·273	0·270	0·0381
10	0·337	0·332	0·0585
12	0·398	0·390	0·083
14	0·457	0·443	0·115
20	0·613	0·575	0·210
25	0·718	0·650	0·304
30	0·800	0·693	0·400
35	0·867	0·708	0·498
40	0·900	0·697	0·586
45	0·945	0·666	0·666

If we have a perpendicular plane—*i.e.*, a plane at an angle of 90 degrees—of 500 square feet, moving forward at a speed of 20 miles an hour, this speed would cause a pressure of about 1¼ lbs. per square foot—altogether 520 lbs. If we incline the plane at an angle of 4 degrees to the horizontal, the "lift" would be 0·139 of 520 lbs., and the "drag" or necessary thrust of the propeller, would be 0·0097 of 520 lbs.

WIND

From Beaufort Scale of Wind Force

General Description of Wind.	Specification of Beaufort Scale. For use on Land, based on Observations made at Land Stations.	Mean wind force at standard density.		Equivalent velocity in miles per hour.
		mb.	Lbs. per sq. ft.	
Calm	Calm ; smoke rises vertically	0	0	0
Light air	Direction of wind shown by smoke drift, but not by wind vanes.	·01	·01	2
Slight breeze	Wind felt on face ; leaves rustle ; ordinary vane moved by wind.	·04	·08	5
Gentle breeze	Leaves and small twigs in constant motion ; wind extends light flag.	·13	·28	10
Moderate breeze	Raises dust and loose paper ; small branches are moved.	·32	·67	15
Fresh breeze	Small trees in leaf begin to sway ; crested wavelets form on inland waters.	·62	1·31	21
Strong breeze	Large branches in motion ; whistling heard in telegraph wires ; umbrellas used with difficulty.	1·1	2·3	27
High wind	Whole trees in motion ; inconvenience felt when walking against wind.	1·7	3·6	35
Gale	Breaks twigs off trees ; generally impedes progress.	2·6	5·4	42
Strong gale	Slight structural damage occurs (chimney pots and slates removed).	3·7	7·7	50
Whole gale	Seldom experienced inland ; trees uprooted ; considerable structural damage occurs.	5·0	10·5	59
Storm	Very rarely experienced ; accompanied by widespread damage.	6·7	14·0	68
Hurricane	- - - - - - - - - -	8·1	Above 17·0	Above 75

DIRECTION OF THE WIND IN ENGLAND

(Observations by Kamtrz)

	Percentage of days.	Average of days per annum.
North	8·2	30·0
North-East	11·1	40·5
East	9·9	35·8
South-East	8·1	29·9
South	11·1	40·5
South-West	22·5	82·1
West	17·1	62·4
North-West	12·0	43·8
	100·	365·

DISTANCE OF HORIZON AT VARIOUS HEIGHTS

A = Height of observer's eye. B = Distance of Horizon

A feet.	B miles.
5	2·739
10	3·874
20	5·480
50	8·664
100	12·253
200	17·329
500	27·399
1000	38·749
2000	54·799
3000	67·115
4000	77·498

WEIGHT OF GASES

	Spec. Gravity.	Weight of 1 cu. foot in lbs.
Carbonic Acid	·00197	·123
Hydrogen	·0000895	·0056
Nitrogen	·00125	·078
Oxygen	·00143	·089
Coal Gas	·0004	·034
Air	·001293	·08072
Water	1·00	62·425
Petrol	0·70	44

WEIGHT OF ATMOSPHERE

14·706 lbs. per square inch.
29·92 inches of mercury (89 inch section).
33·7 feet of water (do.).

The barometer falls about one inch for every rise of altitude of 1000 feet.

USEFUL TABLES

Here will be found tabulated information which may prove useful to the reader. The dimensions of flying-machines are almost invariably given in the metric system, and the more frequent calculations that have to be made form the basis of the table given.

There are also comparative tables relating to woods, flight, gases, meteorology, and other matters.

THE METRIC SYSTEM

The following rules do not give the results to the last decimal point. They are rough calculations, giving approximate results.

Metres. A metre is about 3¼ feet—to be accurate, 39·37 inches. To convert metres into feet, multiply by 39·37 and divide by 12, or multiply by 3·28.

Kilometres. A kilometre is five-eighths of a mile.

Cubic Metres. A cubic metre is 1·30802 of a cubic yard. To convert a cubic metre into cubic feet, multiply by 35·3. This is near enough for general purposes. To convert square metres into square feet, multiply by 11.

SPEEDS

To convert miles per hour into feet per minute, multiply by 88.

The velocity per second is, of course, one-sixtieth of the velocity per minute.

To convert feet per second into miles per hour, multiply by 15 and divide by 22.

To convert miles per hour into kilometres per hour, multiply by 8 and divide by 5.

To convert miles per hour into metres per second, multiply by 9 and divide by 20.

WEIGHT

There are 453·59 grammes in a pound (lb.). A gramme is about 15½ grains.

To convert pounds into kilogrammes, multiply by 9 and divide by 20.

A litre is about 1¾ pints.

MILLIMETRES

65 millimetres . . . . = 2½ inches.
85 ,, ... = 3⅓ ,,
90 ,, ... = 3½ ,,
100 ,, ... = 4 ,,

WIND VELOCITY

Equivalents of Miles-per-Hour in Metres-per-Second

Miles per Hour.	0	1	2	3	4	5	6	7	8	9
0	0·0	0·4	0·9	1·3	1·8	2·2	2·7	3·1	3·6	4·0
10	4·5	4·9	5·4	5·8	6·3	6·7	7·2	7·6	8·0	8·5
20	8·9	9·4	9·8	10·3	10·7	11·2	11·6	12·1	12·5	13·0
30	13·4	13·9	14·3	14·8	15·2	15·6	16·1	16·5	17·0	17·4
40	17·9	18·3	18·8	19·2	19·7	20·1	20·6	21·0	21·5	21·9
50	22·4	22·8	23·2	23·7	24·1	24·6	25·0	25·5	25·9	26·4
60	26·8	27·3	27·7	28·2	28·6	29·1	29·5	30·0	30·4	30·8
70	31·3	31·7	32·2	32·6	33·1	33·5	34·0	34·4	34·9	35·3
80	35·8	36·2	36·7	37·1	37·6	38·0	38·4	38·9	39·3	39·8
90	40·2	40·7	41·4	41·6	42·0	42·5	42·9	43·4	43·8	44·3

Equivalents of Metres-per-Second in Miles-per-Hour

Metres per Second.	0	1	1	3	4	3	6	7	8	9
0	0·0	2·2	4·5	6·7	9·0	11·2	13·4	15·7	17·9	20·1
10	22·4	24·6	26·8	29·1	31·3	33·6	35·8	38·0	40·3	42·5
20	44·7	47·0	49·2	51·5	53·7	55·9	58·2	60·4	62·6	64·9
30	67·1	69·4	71·6	73·8	76·1	78·3	80·5	82·8	85·0	87·2
40	89·5	91·7	94·0	96·2	98·4	100·7	102·9	105·1	107·4	109·6

THERMOMETER.—COMPARISON BETWEEN THE SCALES OF FAHRENHEIT AND CENTIGRADE

Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.
100°	212·0°	62°	143·6°	24°	75·0°	14°	6·8°
99	210·2	61	141·8	23	73·4	15	5·0
98	208·4	60	140·0	22	71·6	16	3·2
97	206·6	59	138·2	21	69·8	17	1·4
96	204·8	58	136·4	20	68·0	18	—
95	203·0	57	134·6	19	66·2	19	2·2
94	201·2	56	132·8	18	64·4	20	4·0
93	198·4	55	131·0	17	62·6	21	5·8
92	197·6	54	129·2	16	60·8	22	7·6
91	195·8	53	127·4	15	59·0	23	9·4
90	194·0	52	125·6	14	57·2	24	11·2
89	192·2	51	123·8	13	55·4	25	13·0
88	190·4	50	122·0	12	53·6	26	14·8
87	188·6	49	120·2	11	51·8	27	16·6
86	186·8	48	118·4	10	50·0	28	18·4
85	185·0	47	116·6	9	48·2	29	20·2
84	183·2	46	114·8	8	46·4	30	22·0
83	181·4	45	113·0	7	44·6	31	23·8
82	179·6	44	111·2	6	42·8	32	25·6
81	177·8	43	109·4	5	41·0	33	27·4
80	176·0	42	107·6	4	39·2	34	29·2
79	174·2	41	105·8	3	37·4	35	31·0
78	172·4	40	104·0	2	35·6	36	32·8
77	170·6	39	102·2	1	33·8	37	34·6
76	168·8	38	100·4	Zero	32·0	38	36·4
75	167·0	37	98·6	1	30·2	39	38·2
74	165·2	36	96·8	2	28·4	40	40·0
73	163·4	35	95·0	3	26·6	41	41·8
72	161·6	34	93·2	4	24·8	42	43·6
71	159·8	33	91·4	5	23·0	43	45·4
70	158·0	32	89·6	6	21·2	44	47·2
69	156·2	31	87·8	7	19·4	45	49·0
68	154·4	30	86·0	8	17·6	46	50·8
67	152·6	29	84·2	9	15·8	47	52·6
66	150·8	28	82·4	10	14·0	48	54·4
65	149·0	27	80·6	11	12·2	49	56·2
64	147·2	26	78·8	12	10·0		
63	145·5	25	77·0	13	8·6		

Zero Fahrenheit corresponds with minus 17·78 Centigrade.

Nine degrees of Fahrenheit equal 5 degrees of Centigrade. Freezing-point Fahrenheit is 32 degrees. This is the zero in Centigrade.

Fahrenheit.	Centigrade.
32	0

TO CONVERT FAHRENHEIT TO CENTIGRADE

If you add 9 degrees to Fahrenheit freezing-point you have a temperature of 41 degrees Fahrenheit, the Centigrade equivalent being 5 degrees.

Fahrenheit.	Centigrade.
32 degrees.	0 degrees.
32+9=41 „	0+5= 5 „
41+9=50 „	5+5=10 „
50+9=59 „	10+5=15 „
59+9=68 „	15+5=20 „

BIRD FLIGHT

The following table is based upon Mouillard's Table of Bird Flight:

	Weight in lbs. per square foot of Wing Surface.
Bat	0·131
Swallow	0·276
Lark	0·327
Sparrow-hawk	0·333
Sparrow	0·414
Gull	0·426
Owl	0·443
Kite	0·457
Crane	0·495
Rook	0·575
Plover	0·725
Buzzard	0·795
Egyptian Vulture	0·848
Quail	0·927
Grey Pelican	1·365
Wild Goose	1·708
Turkey	1·910
Duck (female)	2·008
Duck (male)	2·280

RAPIDITY OF WING MOVEMENT

(Marey's Table)

	Complete Beats per Second.
Common fly	330
Drone fly	240
Bee	190
Wasp	110
Dragon-fly	28
Butterfly	9
Sparrow	13
Wild duck	9
Pigeon	8
Screech-owl	5
Buzzard	3

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